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PROCEEDINGS:
A WORKSHOP ON POLICY AND TECHNICAL ISSUES PERTINENT TO THE DEVELOPMENT OF ENVIRONMENTAL PROTECTION CRITERIA FOR RADIOACTIVE WASTES

ALBUQUERQUE, NEW MEXICO

APRIL 12-14, 1977

THE UNITED STATES
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A WORKSHOP ON

POLICY AND TECHNICAL ISSUES PERTINENT TO THE DEVELOPMENT OF ENVIRONMENTAL PROTECTION CRITERIA FOR RADIOACTIVE WASTES

12-14 April 1977, Albuquerque Inn/Convention Center, Albuquerque, New Mexico
Sponsored by the Office of Radiation Programs, U.S. Environmental Protection Agency

This Workshop was sponsored by the Environmental Protection Agency to provide the opportunity for additional public involvement in the Agency's process for developing proposals for guidance and standards for radioactive waste disposal. The views expressed by the authors in both their original contribution and in various summarized forms throughout these proceedings do not necessarily represent the views of the Agency, but are those of the participants in the Workshop.

POLICY AND TECHNICAL ISSUES
PERTINENT TO THE DEVELOPMENT OF
ENVIRONMENTAL PROTECTION CRITERIA
FOR RADIOACTIVE WASTES*

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* This document is the result of a Workshop sponsored by the Environmental Protection Agency, and held on 12-14 April 1977 in Albuquerque, New Mexico.

† These sections of this document were produced prior to the Albuquerque Workshop by the EPA.

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PREFACE

The Environmental Protection Agency is developing environmental protection criteria for radioactive waste to assure protection of the public health and the general environment. In order to provide a means for interested members of the public to participate in the development of these criteria, EPA has held a series of public Workshops to address public policy issues. The first Workshop, entitled "Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes," was held in Reston, Virginia, on 3-5 February 1977. This, the second Workshop, focusing on policy and technical issues relevant to developing such criteria, was held at the Albuquerque Inn/Convention Center, Albuquerque, New Mexico, on 12-14 April 1977. The Workshop was attended by over 280 persons from diverse backgrounds, including public interest groups, government, industry, and academia, all of whom had the opportunity to participate. The purpose of this document is to record in summarized form the proceedings of this Workshop.

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INTRODUCTION

Radioactive wastes exist in a variety of forms, concentrations, and quantities. These include categories such as low-level, intermediate-level, and high-level wastes. Many of these wastes, especially those which result from nuclear weapons programs and nuclear power generation programs, may also contain sufficient concentrations of certain heavy elements to be designated as transuranic wastes (TRU). These wastes are important since they are characteristically quite toxic and are long-lived. Other long-lived wastes are those containing naturally occurring radioactivity which has been redistributed by human activities. Examples are uranium mill tailings and residues from phosphate and other mining operations. Other low-level and intermediate-level radioactive wastes result from medical, dental, industrial, and scientific radioisotope applications, and the decommissioning of contaminated equipment. While public concern is most often expressed with regard to high-level waste, criteria must be formulated for environmentally sound dispositions of all forms of radioactive waste.

Several terms appear to be generic to any discussion of radioactive waste; therefore the Environmental Protection Agency (EPA) chose to provide a list of working definitions which are in the form of glossaries following each topical Issues and Objectives Statement. As used by EPA in these statements, the term Radioactive Waste refers to all retained radioactive materials for which no immediate or foreseeable use is intended, produced as by-products of human activities. Waste management, as used here, describes the entire range of activities and associated technologies for dealing with radioactive waste. There are also two basic terms for waste management options: Storage and Disposal. The difference between storage and disposal lies mainly in the degree of institutional control required to maintain isolation of the waste from the biosphere. Isolation through storage will depend upon engineered facilities and institutional activities, while isolation through disposal will be achieved by utilizing the long-term stability of barriers occurring in nature (e.g., deep geologic strata such as subsurface salt deposits, and seabeds). Other disposal methods would eliminate the waste from existence on the earth, by transmutation of the elements or by transportation of the waste away from the planet.

There is considerable public concern over the technical feasibility and economic practicability of providing environmentally secure disposal for all radioactive wastes. Consequently, the United States is faced with an urgent need to demonstrate a solution to this problem. The first method may not be the one ultimately or exclusively used, but a need exists to demonstrate that such wastes can be contained in an environmentally sound manner. Key questions arise: How soon can we have acceptable permanent disposal methods for the radioactive

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wastes already on hand? How effective will those methods be? How much will they cost?

Future increases in the amount of radioactive waste materials in the United States will depend upon the specific policies the country adopts regarding energy production, mineral utilization, research, and other activities. Regardless of future policies, however, it may be best to expeditiously find suitable solutions so that disposal of all radioactive wastes can take place in a manner which will ensure adequate protection of the environment and public health.

A variety of waste disposal methods currently appear technologically promising. However, careful consideration must be given to developing the means to evaluate the environmental impacts of the technical alternatives, to assure that those methods selected for implementation will meet environmental objectives. Formulating these environmental and public health objectives requires the active participation and interaction of the public, industry, and the responsible Federal and state agencies.

The EPA is conducting a program to develop environmental radiation protection criteria and generally applicable environmental standards. In addition to these activities, specific standards and regulations will be developed as required by the Ocean Dumping Act and the Resource Conservation Recovery Act. The environmental radiation standards (numerical limits) will be implemented by the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC) through their respective responsibilities in the field of radioactive waste management.

The purpose of "A Workshop on Policy and Technical Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes" was to address these issues for all types of radioactive waste. The information thus developed will constitute an important input to the development of environmental criteria by EPA.

A previous Workshop was held in Reston, Virginia on 3-5 February 1977, and the Proceedings (U.S. EPA, Report OPR/CSD-77-1), are available from EPA without charge. A second Workshop took place in Albuquerque, New Mexico on 12-14 April 1977. There were three topical areas addressed at the Albuquerque Workshop: Policy and Technical Considerations for High-Level, and for Intermediate-Level and Low-Level Radioactive Waste, and Public Acceptability of Risk Associated with Radioactive Waste. The sessions were designed to address key issues in each of the three topical areas from all points of view, while concentrating on especially important matters which either were not addressed at Reston, or were otherwise unresolved.

The format of the Workshop was kept as informal as practicable, consistent with the order required to afford all participants equal opportunities to present their views.

Most of the first day of both Workshops consisted of a plenary session, during which invited participants presented papers on issues of their choice, within each of the topical areas. These selected speakers were known to span widely diverse interests and viewpoints, and were expected to provide a broad range of opinions. In addition, any other persons who wished to present a formal statement were permitted to do so, and copies of these and other submitted statements are included in these Proceedings.

The remaining day and a half was devoted to the small participative working sessions, each addressing one of the three major topics of the Workshop. Each session was moderated by a member of EPA's legal staff, and several EPA technical staff members were present to benefit from the discussions and to explain the Agency's responsibilities and its needs for guidance from the Workshop. The EPA staff had no intention, however, to influence the substance of the Workshop's deliberations. No relevant subject was excluded nor were the participants required to address any prescribed list of items, although suggested subjects were provided in advance by EPA. Members of each working group themselves developed in their first sessions an agenda to be addressed relevant to their own topical area.

Following its discussions, each working group convened an Executive Session to prepare a summary report including all consensus views as well as many individual expressions of opinion on major items of discussion. These Summaries and Conclusions, which were approved by the full working group prior to the final plenary session are included in these Proceedings. These Summaries and Conclusions were then presented to a final plenary session, open to comments and questions from all Workshop participants.

This document is a record of the proceedings of the Albuquerque Workshop. It begins with a Summary and Overall Assessment of the Workshop, prepared by the EPA staff, which highlights the principal substantive conclusions that may be drawn from the working group reports. Under each major topical heading will appear the appropriate section of the Issues and Objectives Statements, developed by EPA prior to the Workshop for the edification of the participants, and the text for the presentations given by the invited speakers. The Proceedings also contain the Summary and Conclusions of each working group, and the audience response to these reports as solicited during the last plenary session of the Workshop. Written statements submitted by those other than the invited speakers are included near the end of the document.

SUMMARY AND OVERALL ASSESSMENT OF THE WORKSHOP

The majority of the first day of the Albuquerque Workshop was spent in plenary session, during which formal presentations were made by the fourteen invited speakers. These were relatively short (15 minutes), fairly general, and representative of the diversity of opinions on factors to be included in criteria for disposal of radioactive waste. The presentations generally reflected subject matter related to the three topical areas to be addressed in the working group sessions to follow: Policy and Technical Considerations for High-Level Radioactive Waste, for Intermediate-Level and Low-Level Waste, and Public Acceptability of Risk Associated with Radioactive Waste.

The first working group session for each of the three working groups was held late in the afternoon of the first day, in order to settle organizational matters and to decide on working definitions to be used in the following discussion. There was considerable discussion concerning the wording of these definitions, which continued into the second session that evening. The remainder of the session consisted of a review of the respective Summary of Considerations for each topical area, as presented in the Issues and Objectives Statement. The participants reached agreement on the items to be covered in the following sessions, including a number not specifically addressed in the Environmental Protection Agency's (EPA) suggested list. The issue points were then compiled by the working group moderators into a final list for distribution the following day.

The two, three-hour working sessions the second day were used to address the issues raised for consideration and to reach consensus where possible. This latter effort was complicated, in comparison to the Reston Workshop, by the large number of participants in attendance at the working sessions. Working Group 2 made a decision to alleviate the communication problems inherent in such a large group by splitting into two subgroups of approximately 35 apiece, addressing, respectively, naturally radioactive low-level waste and all other low-level and intermediate-level waste.

As with the Reston Workshop, there were many opinions expressed which either overlapped from working group to working group, or were generally applicable to the development of criteria for all radioactive wastes. These are summarized below without specific mention of the working group from which they evolved.

1. General agreement was reached that the criteria that EPA will be developing should apply to waste management and not address disposal alone. This consensus, in one group, evolved from a discussion of the definition of disposal. It was felt that because waste disposed of by almost any method could be recovered if enough resources were invested, the underlying

factor is the ease of recovery. In addition, one group endorsed a definition of waste management, which includes the entire range of activities for dealing with radioactive waste, including reprocessing, transportation, storage, and disposal. The point was made by a number of participants, however, that some of these activities are outside of EPA's purview and not mandated for the Waste Environmental Standards Program.

2. A consensus was reached that all unplanned events and accidents should be considered by EPA in developing criteria and setting standards for radioactive waste. Neither of the groups could reach consensus, however, on how this consideration should be addressed in the criteria. It was contended, though, for high-level waste, that the forthcoming environmental statement for the commercial nuclear waste management program would probably not include analyses of the worst conceivable accident and failure probabilites of waste storage and disposal facilities under consideration, namely, deep geological storage and disposal (deep burial), and retrievable surface storage facilities. It was further contended that this was not wise, and that in order to ensure the formulation of sound environmental protection, criteria and standards should require that a complete hazard analysis be made prior to such formulation.

3. Retrievability should be considered only when safety will not be compromised. It was generally conceded that there may be bases for retrievability, such as potential resource value, or the need for some period or degree of institutional control, but these must be superseded by the overriding concern for site integrity. It became evident, however, that there are various degrees of retrievability, dependent upon the length of time this option would be available. Thus, there could be a range of compromises.

4. There was considerable discussion generated concerning whether all categories of waste should be treated consistently by the criteria, as suggested at the Reston Workshop, or whether, in fact, this was not feasible due to the disparate characteristics of these various waste types. It was generally concluded that it is desirable for the criteria to address radiation exposure, regardless of its source, and therefore it would not be appropriate for them to distinguish between waste types.

5. The long-term implications of radioactive waste management were discussed at length, with many participants supporting the premise that the wastes should

be managed so that the risk to future generations would be no greater than we are willing to accept for ourselves. In discussing the period of time during which long-term safety considerations should be addressed, it was suggested by a large segment of the participants that the concept of an "unending" period of time should be employed. It was not clear, however, that safety for future generations would be greater or less than for present ones because of uncertainties in projections of the long-term effectiveness of containment systems. It was also emphasized by some participants that this generation has relatively little control over the stability of future societal institutions and therefore, the criteria should more appropriately address a specified future time. It was also felt that the EPA standards that would be based on the criteria to be developed should be set at a level low enough to protect the health of present and future populations, regardless of the ability of the industry to meet them.

6. The appropriate means to address upper and lower individual and population dose limits was discussed by one working group. It was generally agreed that both maximum individual and population dose limitations should be considered, and that natural background radiation levels are the appropriate lower limit, below which efforts to clean up an area would not be justified.

7. It was suggested that EPA should make a considerable effort to broaden the general public's information base concerning radioactive waste so that more effective input would be possible. There was considerable disagreement as to the optimal method to use, with various modes of mass communication being suggested.

The Workshop appeared to achieve its goal of eliciting public concerns about radioactive waste. Although the diverse and often opposing backgrounds and opinions of the participants, again, made it difficult to reach consensus on controversial issues, the groups were successful in delineating the major factors underlying these issues that EPA would have to consider when developing the criteria.

Although one objective of the Albuquerque Workshop was to use the results of the Reston Workshop as a basis for further issue identification and deliberation, a number of issues were restated and reaffirmed at Albuquerque. These included addressing unplanned events and accidents in the development of criteria (EPA should) and how to address the various waste types (EPA should address them uniformly).

As postulated at the Reston Workshop, the Albuquerque Workshop participants affirmed that public involvement and acceptance, with the related requirement for comprehensible, applicable, and acceptable definitions, are integral to the mechanics of developing criteria and standards. It was generally agreed that public forums such as these, despite their shortcomings, do provide one means to obtain such input.

OVERVIEW OF POLICY AND TECHNICAL CONSIDERATIONS

INTRODUCTION

The presence of radioactive wastes and their potential for impact on the environment and public health require the establishment of environmental radiation protection criteria and generally applicable environmental standards. The Environmental Protection Agency (EPA) therefore has undertaken a program to provide environmental protection criteria and numerical standards for management and disposal of high-level wastes. Currently, there is considerable public concern over the technical and economic practicability of providing environmentally adequate permanent disposal for radioactive wastes. Thus, it is essential that the development of the criteria and standards involve active participation by, and interaction with, the public. One mechanism to promote such interaction is the public workshop.

The EPA sponsored its first Radioactive Wastes Workshop in Reston, Virginia, on 3-5 February 1977. The intent of the Workshop was to focus public policy issues concerning radioactive waste management and disposal. The topics addressed at Reston were: Approaches to Criteria Development; Risk Considerations; and Long-Term Implications. Although the discussions at Reston were kept in the context of public policy, some technical issues were considered in a secondary sense.

The purpose of the Workshop at Albuquerque is to go forward from the base of information and issues identified at Reston. As was the case at Reston, this Workshop, although organized by EPA, is to be conducted such that the conclusions reached or recommendations made are determined only by the participants in the various working groups.

GOALS

The general goal of this Workshop is to discuss technical problems and issues that are basic to developing environmental protection requirements for all types of radioactive wastes. A particular objective is to develop clear perspectives of the compatibility or incompatibility between public policy issues and technical issues. Where such compatibility does not exist, the basis of the conflict will be explored and considerations will be given to potential alternatives for compromise. The topical discussions which follow this overview are designed to develop the technical issues and to relate those issues to information gained at Reston. You will note that the topical papers of this document do not provide answers to issues but pose questions. This interrogative format is designed to focus the discussions of the participants at the Workshop.

Many public issues relating to environmental protection criteria for radioactive wastes were discussed at the first Workshop. It was generally agreed that it is desirable to define such criteria, even though they may be difficult to formulate for all types of radioactive wastes. One point of concern, however, is that the first Workshop tended to concentrate on high-level, long-lived wastes. It may well be that many perceptions made at that Workshop are not applicable to any other than high-level waste disposal. A major goal of this second Workshop will be to discuss the problems of all of all the types of radioactive wastes, their potential environmental and public health impacts, and the variability of technical factors among waste types and disposal methods.

The discussions at this Workshop will explore three important considerations:

1. Are the bases of criteria favored by the Reston Workshop realizable in the face of technical and economic problems for high-level wastes?
2. If so, are they also applicable to other forms of radioactive waste?
3. If not, what are the bases of the inconsistencies, and what adjustments can be made in either technical and economic areas or public expectations to deal with such inconsistencies?

PUBLIC ISSUES

With respect to criteria development, the summary papers from the first Workshop identified several considerations for EPA to include in environmental protection criteria. It would be useful to keep the major ones in mind as a perspective for discussions at the second Workshop. For example, it was agreed that criteria should promote containment and/or isolation by physical and environmental barriers and that minimizing long-term risk should be given the highest design priority. It may be desirable to explore how many and what types of barriers would minimize environmental impact and exposure of the public.

Considerable discussion was devoted to the manner in which criteria should deal with risk. It was generally felt that determinations of the potential exposures of people in this and future generations and in particular geographical areas should be required and that these analyses should be performed by established methods. It also appeared to be important to examine the degree to which intrusion, accidental disruption, or failure of physical and environmental barriers could enable radioactive wastes to enter environmental pathways.

Long-term implications of radioactive waste were also of interest to the participants in the first Workshop. It was concluded that criteria should require methods of disposal that protect both present and future generations. In this regard, criteria should be such that, once disposal is complete, no institutional framework would be required to provide environmental and public health protection. What was not determined was for how long such protection should be required.

Two other areas which were discussed at Reston were public and technical considerations of retrievability and monitoring. It was generally agreed that retrievability of high-level radioactive waste should be required during operational and validation phases of waste disposal. Sufficient monitoring of waste operations should be conducted in order to ascertain the ability of the method to meet environmental protection requirements. The value of monitoring after disposal was completed was considered doubtful.

TECHNICAL ISSUES

It is important to consider technical constraints associated with the types of waste in developing environmental critera. Radioactive waste types are often roughly termed high-level, intermediate-level and low-level. The latter encompasses tailings and mining residues that contain appreciable quantities of redistributed natural radioactivity. Deep geological isolation is currently being considered for disposal of high-level wastes; surface or near-surface burial is currently used for other wastes.

Disposal by surface or shallow land burial seems to be inconsistent with resolutions by participants at Reston with respect to retrievability, monitoring, and isolation without dependency on social institutions. Also, if a goal of "zero planned release" to environmental pathways from any disposal method is either desired or expected, it probably is unrealistic for surface disposal of mill tailings which produce steady radon exhalation for thousands of years. Such a goal may, however, be more nearly realizable for deeply buried wastes. This illustrates how the potential environmental impacts of wastes differ according to waste type.

Wastes also differ with respect to the time dependence of their potential hazards. Although there is some controversy regarding fine points of the definition of high-level waste, they initially are extremely radioactive in even small quantities. They decay in a few hundred years to a level that is dominated by the long-lived alpha-emitting transuranics (TRU), which then persist for tens of thousands of years. Both this "hot" component that is reduced considerably in a few hundred years, and the long-lived, low-activity, toxic, alpha-emitting component are very important in determining the mode of disposal and the period of required isolation.

Low-level and intermediate-level wastes are generally understood to include radionuclides of relatively short half-lives or of low-activity concentration. To date, control of low-level and intermediate-level waste has been limited to temporary storage, placement in the ground, and disposal in the ocean.

Low-level and intermediate-level wastes, with the possible exception of TRU contaminates, pose problems only for several decades. Because of the nature of surface or shallow land burial, however, there is generally an elevated external radiation field over the site during the active period. Thus, environmental protection criteria for such wastes may rely on institutions up to a point. If shallow land burial operations are to be conducted, the near-term impacts could be important, and should be thoroughly evaluated. Any inconsistencies between these apparent requirements and those expressed in the first Workshop where high-level waste primarily was addressed need to be resolved. It may also be difficult to reconcile the retrievability and monitoring requirements of surface disposal which involves huge volumes of material, since much smaller volumes often are associated with other forms of disposal.

TOPICS FOR DISCUSSION

The sections following will address the above considerations in a format that relates key issues to the discussions that took place at the Reston Workshop. Apparent inconsistencies in need of further discussion will be identified, and new issues will be raised. Such issues will be addressed as they relate to high-level wastes in Topic 1 and to low-level and intermediate-level wastes in Topic 2. Topic 3 concerns the process being used to determine the public's perspective, whether that mechanism will aid in public acceptability of the standards, and whether more, less, or different things ought to be done in the overall public interest with respect to determining criteria for radioactive waste disposal.

Several terms appear to be generic to all discussions of radioactive waste; therefore, a glossary of working definitions for general terms is included in this section. Terms which apply specifically to one of the major topics of the Workshop will be appended as definitions in the Issues and Objectives Statement for that topic. Participants are encouraged to comment on the usefulness and suitability of these definitions when the respective Working Groups begin their deliberations.

OVERVIEW GLOSSARY

Containment - Keeping radioactive waste within the defined confines of its disposal site.

> Container Barrier - Physical properties of waste containers serving to prevent dispersal of radioactive waste.
>
> Natural Barrier - Geologic media exhibiting physical properties that inhibit the dispersion of radioactive wastes.
>
> Waste Form Barrier - A barrier consisting of the physical form of the radioactive waste itself (calcines, glassification, etc.) inhibiting dispersal or leaching.

Criteria, Environmental Radiation Protection - The environmental radiation protection criteria for waste management will be a generalized Agency policy statement detailing the basic philosophy, conditions, and issues that must be considered and reflected in the development of generally applicable environmental radiation standards and in the selection of appropriate waste disposal technologies and sites.

Disposal - The isolation of radioactive waste in a manner that precludes recovery, or its placement in a manner that involves natural barriers and is considered permanent so that recovery is not provided for.

Federal Radioactive Waste Repository - A facility owned and operated by a Federal agency for the storage or disposal of radioactive wastes.

> Operational Phase - Period during which waste is received and emplaced at a repository.
>
> Validation Phase - Period during which the integrity and performance of the repository may be verified. The waste would be retrievable during this phase.
>
> Disposal Phase - Period that follows a determination that the repository is functioning satisfactorily. No further activities other than monitoring (possibly) are envisioned.

Isolation - The location of a radioactive waste in such a place that further contact between the waste and the human environment is highly unlikely.

Legacy - The bequeathing or passing on of radioactive wastes and their incumbent risks to future generations.

Management - A generic term describing the entire range of activities for dealing with radioactive waste, including processing, transportation, storage, and disposal. A given set of such activities and the technologies by which they are implemented constitutes a management system.

Monitoring - A routine program to measure the quantity of the discharges from a waste disposal operation and their impact on the surrounding region, or to measure changes in physical, chemical, or biological characteristics of the site.

Public - Those individuals other than the Federal officials having responsibilities in the area of radioactive waste management.

Retrievability - A designed capability to remove waste from its place in storage.

Risk - The general concept of "risk" includes the probability (or possibility) of loss, damage, or injury and the consequences (or magnitude) of the loss, damage, or injury. A common representation of risk is: risk equals probability times consequence.

Storage - Retention of radioactive waste in some form or location at facilities with designed provisions for retrieval.

> Storage, Long Term - The storage of wastes in a form and location such that no further processing or manipulation is considered necessary for a period of time that is very long compared to other periods of time in the nuclear fuel cycle.

Waste, Radioactive - All retained radioactive materials for which no immediate or foreseeable use is intended generated high-level (HLW) and transuranic-contaminated waste (TRU), both produced through activities associated with military weapons production and nuclear power generation; wastes from medical and dental radioisotopic applications; uranium mill tailings; waste products associated with decommissioning activities; and mining activity wastes, such as phosphate tailings, in which appreciable quantities of naturally occurring radioisotopes are redistributed.

Zero Planned Release - A design criterion such that leakage of radioactivity across any barrier is not anticipated.

OPENING ADDRESS

William D. Rowe, Ph.D.

Deputy Assistant Administrator for Radiation Programs
U.S. Environmental Protection Agency
Washington, D. C.

Ladies and Gentlemen: It is my pleasure to welcome you to our second Workshop on environmental protection criteria for radioactive wastes. We appreciate your participation in this endeavor to address in a fully open working forum the various issues involved. Since we hope to elicit maximum participation by all interested parties, we are pleased that we could hold this Workshop in the Southwest to obtain views of participants who are closely related to local considerations.

The presence of radioactive wastes, their continued production, and the potential for significant impacts on the environment and the public require the establishment of environmental radiation protection criteria and generally applicable environmental standards. Because of its responsibilities, EPA has undertaken to provide the criteria and standards necessary to assure environmental protection during the development and implementation of waste disposal methodologies.

This program is being carried out under the two basic authorities derived from the Atomic Energy Act and Reorganization Plan No. 3 of 1970 for setting radiation protection standards: (1) EPA's responsibility to set generally applicable environmental standards outside the boundaries of sites which possess radioactive materials that are subject to regulation under the Atomic Energy Act; and (2) the functions of the former Federal Radiation Council to provide Federal radiation guidance for all radiation directly or indirectly affecting health.

President Ford's message on reprocessing and the export of nuclear technology specifically required EPA to set numerical standards for high-level waste by the middle of calendar year 1978. We expect to achieve that goal by two distinct but interrelated program efforts. The first of these is to develop criteria on which to base the standards. In parallel and sometime after the criteria are developed, a technical environmental assessment of high-activity, long-lived wastes will be used within the framework of the criteria to arrive at numerical standards for these wastes.

I should note at the outset that any standards that EPA sets will be neither site- nor method-specific. The regulation of waste management operations rests with the Nuclear Regulatory Commission (NRC), whose regulations when promulgated will assure that EPA standards are met. The Energy Research and Development Administration (ERDA) is responsible to develop the technology and operate high-level waste disposal sites, in conformance with NRC regulations. ERDA is also responsible for managing all of the defense-related radioactive waste throughout the country.

Because of considerable public concern over the technical and economic practicability of providing environmentally adequate permanent disposal for radioactive wastes, it is essential that the development of such requirements involves active participation by and interaction with the general public.

In order to promote such interaction, EPA has, as most of you know, already sponsored a Workshop in Reston, Virginia, on 3-5 February 1977. The Reston Workshop focused on issues concerning radioactive waste management in the broad sense of public policy; technical issues were considered in a secondary sense. The proceedings of the Reston Workshop have been published and distributed to the participants and the registrants.

The main purpose of this, the second Workshop, is not to repeat the discussions held at the first Workshop in another part of the nation but to build on the information developed thus far. As was the case for Reston, this Workshop, although organized by EPA, is to be conducted so that the conclusions reached or recommendations made are determined only by the participants in the various working sections.

The general goal of this Workshop is to use the same participative framework to discuss technical problems and issues that are also basic to developing environmental protection requirements for radioactive wastes. The first Workshop tended to focus primarily on high-level, long-lived wastes; thus, it may well be the case that most perceptions of the problem, their solutions, and requirements that the Reston Workshop to any other than high-level waste disposal. A major goal of this second Workshop will be to discuss the problems of all the forms of radioactive wastes, their potential environmental and public health impacts, and the variability of technical factors among the types of waste and methods of disposal. We hope the discussions will focus on three important areas: (1) are the bases of criteria favored by the first Workshop realizable in the face of technical and economic problems for high-level wastes; (2) if so, are they also applicable to other forms of radioactive waste; and (3) if not, what are the bases of the inconsistencies, and what adjustments can be made in either technical and economic areas or public expectations to deal with such inconsistencies?

Each of you should have received a copy of the Issues and Objectives Statement. This document was prepared to help the participants to focus on the issues for consideration at this Workshop; however, it was not designed to cover all issues nor provide answers to those issues which are raised. Most of this first day is also designed to raise topics for discussion.

People with different points of view have been invited to present views and information issues on three topics. Topics 1 and 2 concern high-level and low-level intermediate-level wastes, respectively. Topic 3 addresses the process being used to determine the public's perspective on acceptability of waste standards. In the latter case, we want to ascertain whether more, less or different things than we are doing ought to be done in the overall public interest with respect to determining criteria for radioactive wastes disposed. We are particularly interested in the degree of conservatism the public may expect for any waste disposal method to be acceptable, the cost of that conservatism, and whether it is a price society ought to pay for acceptability. We have also provided an opportunity (in accordance with the announcement) for additional issues and points of view to be developed as written statements. The authors may present their statements near the end of this plenary session. All such statements will, of course, be published in the proceedings.

Working sessions will meet later this afternoon and all day tomorrow to discuss the three topics covered in the Issues and Objectives document. Each working session will have a discussion leader and all attendees of the session will be equal participants. The discussion leader's role is to assure that there is order and that the results are recorded. A summary paper on each session's deliberations will be prepared by a small representative committee chosen by the Workshop from volunteers, and will include any recommendations or conclusions arrived at by the group. Since some issues probably will not be resolved by a consensus, majority and minority views may also be expressed.

Several terms appear to be important to these discussions of radioactive waste; therefore, we have provided working definitions of terms in glossaries at the end of each topical paper in the Issues and Objective Statements. Participants are encouraged to comment on the usefulness and suitability of these working definitions when the respective work groups begin their deliberations.

At the last day of the session (Thursday morning), a representative of each working session will present its findings to a plenary session so that everybody may know the results of the various efforts. Further opportunity for discussion will be provided.

Any issue may be raised before this Workshop, as long as it deals with development of environmental protection criteria for radioactive wastes. There are two issues for which I want to provide EPA's position. One issue is institutional; the other, philosophical. First, EPA's role in setting environmental standards for radioactive waste is established and, as a matter of policy, will not be subject for consideration at this Workshop. The second issue involves the need to set environmental standards for wastes versus decisions on further generation of wastes, particularly by nuclear power operations. There is no question that considerable amounts of wastes already exist and that these must be disposed of by enviromentally acceptable means; thus, the Agency believes that a program to establish the necessary criteria and standards for such wastes is essential, regardless of whether any more are generated. We will not, therefore, cover at this Workshop the question of whether we should stop generating wastes. Not only do we think the problem is sufficient to require early attention on its own but EPA has no regulatory authority in this area. The question is a broad one and must involve all branches of government. Without diminishing the importance of such a question, I will rule out its consideration at this Workshop since such discussion would only be a diversion from our major and amply justified task of developing environmental protection requirements for such wastes whether present now or generated later.

The factors that are basic to risks and their acceptability are pertinent to this Workshop. Environmental protection requirements should be stated, and these will then determine how any future wastes will be generated and handled. If future activities can meet these requirements then the Agency would deem them environmentally acceptable.

All other substantive issues which affect the setting of waste management criteria are fair game. I hope we can go forward with the Workshop with a spirit of identifying all the issues, discussing them openly to get all points of view, defining where different parties agree and disagree, and devising fruitful approaches for solutions.

To sum up, I hope you will keep in mind that we sincerely want to provide the best forum we can to obtain public input before a single environmental protection criterion is drafted. We look forward to suggestions from the participants on how we can best develop environmental protection requirements for radioactive wastes in the overall public interest.

Thank You.

TOPIC 1

POLICY AND TECHNICAL CONSIDERATIONS FOR HIGH-LEVEL RADIOACTIVE WASTE

POLICY AND TECHNICAL CONSIDERATIONS FOR HIGH-LEVEL RADIOACTIVE WASTES: A STATEMENT OF ISSUES AND OBJECTIVES

INTRODUCTION

High-level wastes include the bulk of the radioactive products of controlled nuclear fission. In the past, the term "high-level waste" has primarily been associated with the highly radioactive liquid or solidified derivatives of that liquid which remain after reprocessing nuclear reactor fuel elements. However, with the growing possibility of a commercial nuclear fuel cycle that does not include reprocessing, the term may also be associated with the spent fuel elements themselves.

A primary hazard of any high-level waste form is the intense concentration of highly radioactive fission products, which must be isolated from any life form. The initially very high fission product activity declines substantially with time, however, so that after about 500 years the remaining hazard of the material is associated with several isotopes having extremely long half-lives.

A major part of the long-term hazard associated with the wastes from nuclear fission are the long-lived transuranic (TRU) nuclides (primarily plutonium, americium, and curium) created through neutron reactions with reactor fuel. These, together with their daughter radionuclides, will constitute sources of radioactivity for millions of years. Because of the high radiotoxicity of the alpha particles they emit, significant concentrations of TRU radionuclides probably should be isolated as stringently as high-level wastes. It may be noted, however, that for at least some forms of high-level waste the remaining radiation hazard after about 1,000 years, which largely results from its TRU content, may be no greater than that associated with certain natural formations, such as pitchblende.

The forms and concentrations of TRU wastes depend strongly upon the characteristics of the nuclear fuel cycle. For example, spent fuel would contain much higher concentrations of TRU radionuclides than high-level waste from reprocessing, since the intent of reprocessing is to recover as much plutonium and uranium as possible. Also, a wide variety of non-high-level wastes will be contaminated with TRU radionuclides to various levels, and the nature of these wastes will depend upon the particular fuel cycles employed.

Past national defense programs account for the great preponderance of existing high-level wastes derived from fuel reprocessing. These military wastes are currently stored in a variety of liquid and solidified forms at Federal facilities at Hanford, Washington; Savannah River, South Carolina; and

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Idaho Falls, Idaho. A comparable amount of radioactivity, however, is also contained in spent fuel elements discharged from commercial power reactors. These fuel elements are primarily stored in spent fuel pools at reactor sites around the country.

The current programs to develop disposal methods for high-level and TRU-contaminated wastes are primarily oriented toward creation of deep geological repositories in continental formations. Through the recently established Office of Waste Isolation, the Energy Research and Development Administration (ERDA) is conducting an extensive survey of potential sites for such repositories, and is investigating other engineering aspects necessary to maximize isolation of these wastes from the biological environment. Other disposal methods that have also been investigated, but are now receiving relatively little emphasis, are extraterrestrial disposal, ocean floor repositories, and ice-sheet repositories.

Against this technical background, there are a number of issues that the Environmental Protection Agency (EPA) must consider in translating broad policy considerations, such as those articulated at the Reston Workshop, into environmental protection criteria for high-level and TRU-contaminated waste. The following sections review these issues and suggest some questions for discussion by the participants at this Workshop.

UNPLANNED OR ACCIDENTAL EVENTS

Deep geological repositories would be planned for locations where no mechanisms for transfer of the waste to the human environment exist or are expected to exist. Against this background the threat of unplanned release predominates. Public concern over high-level waste disposal does not appear to be focused on the ability to get the waste safely into the repository, but rather on the ability of keeping the waste isolated from humans. Unplanned events and accidents, such as appearance of an underground aquifer at the disposal site (leaching), intentional or unintentional intrusion, and low-probability natural calamities (earthquakes, meteorites, volcanoes, etc.) appear to be the most widespread and important concerns relative to protecting the environment.

Establishing criteria and standards to address such unplanned events will involve implementation concepts different from those that will be associated with the Uranium Fuel Cycle (UFC) standards.* The UFC standards, which set limits on the permissible environmental impact of radiation from fuel cycle facilities, will be implemented and enforced (by the Nuclear Regulatory Commission) through monitoring of operating installations. Thus, although practicality dictates that unplanned incidents must influence the designs in order to provide reasonable assurance of eventual compliance, the UFC standards are essentially operational standards. The probabilities and consequences of unplanned events (particularly low-probability events) are not amenable to such monitoring. However, a standard addressing unplanned events could be implemented during the design or preoperational phase.

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* 40 CFR - Part 190.

Although there was strong agreement at the Reston Workshop that the possibility of accidental occurrences was worthy of scrutiny and evaluation, two Working Groups had different views on whether the EPA should address them explicitly in its disposal criteria. If the EPA, however, does decide that criteria should address accidental occurences, what would be an appropriate and effective approach? One method would be to set qualitative limits on the environmental impact allowable from any accidental series of events. How else might environmental protection criteria regarding accidents be formulated?

INSTITUTIONAL CONTROLS AND RETRIEVABILITY

Additional considerations involving unplanned events concern the approaches taken with regard to any "perpetual care" of the repository and possible remedial actions subsequent to accidental radioactivity releases. Both circumstances require human involvement to minimize the potential for harm from the disposed waste. Such dependence requires appropriate instructions to be passed on from generation to generation, and acceptance of the responsibility by future societies. One of the clearest mandates from the Reston Workshop was that waste disposal solutions should not depend on societal institutions over the long term. Does this necessarily imply that the benefits of "perpetual care" and remedial actions should be foreclosed by waste disposal criteria?

Other possible technical features of disposal systems that would be advantageous in several respects appear to conflict with broad principles to which many people subscribe. For example, at the Reston Workshop the consensus was that present and future generations should be protected from nuclear waste. Some possible means of protection involving reliance on future institutions were discussed above. Additional features affording protection are monitoring systems to provide early notice of environmental or geological changes and a design permitting retrieval of the waste to limit the consequences of a repository failure. It is interesting that such protective systems are directly contrary to another widely endorsed aspect for prospective disposal systems, namely, that they should be secure from intrusion.* Furthermore, providing meaningful monitoring or retrievability might significantly increase the risk of a technical failure of the repository. The environmental protection criteria could require, encourage, discourage, forbid, or disregard monitoring or retrievability: which course offers the greatest net benefit?

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* Note, however, that the Reston group felt it was not necessary to guard absolutely against intrusion under all conceivable circumstances.

PERSPECTIVES IN ESTABLISHING CRITERIA AND STANDARDS

A foundation upon which environmental protection criteria and standards for waste disposal must rest is a thorough evaluation of the potential environmental impacts that might be encountered when the radiation source is discarded. It is important also to consider how these projected impacts might vary with different engineering control technologies, long-term care, remedial action, etc. However, these studies are at best only a tool; decision makers in this field also need a perspective--a framework to guide the translation of technical information into appropriate criteria and standards.

The Reston Workshop provided some guidance along these lines, as does a long tradition of Federal activity in radiation protection. For example, it was recommended in general terms that analyses of cost and benefit, risk and benefit, and other related variables, and the concept that exposures should be as low as reasonably achievable should all play a role in developing environmental protection criteria. However, although it was emphasized that such approaches could not be the only bases for decision, it appears that they would tend to lead to different standards for high-level and low-level waste. This inference follows from the characteristics of the primary candidates for disposal technologies, which are deep geological burial of high-level waste, shallow land burial for low-level waste, and management of mill tailings at or near the earth's surface. It appears to be feasible to essentially eliminate planned releases from a high-level waste repository and not feasible to do so for the others. Would it be ethical to require that high-level waste disposal achieve what cannot be achieved for other forms of radioactive waste disposal?

Another closely related matter of perspective was raised at Reston. The EPA was urged by some parties to relate its environmental protection effort in the field of radioactive waste to the activities of EPA and others in controlling other pollutants. What should be the form and basis of any relationship among these efforts?

Other questions of perspective relating specifically to determination of socially acceptable levels of risk will be discussed as Topic 3 of this Workshop.

MULTIPLICITY

It has been noted that under certain conditions the damage resulting from a repository failure due to either technical inadequacy or intrusion could be less consequential if there were a multiplicity of disposal sites. A variation on this strategy calls for development of a number of different methods of disposal to guard against the possibility that unforeseen defects in a single scheme may cause the whole program to fail. It is recognized, however, that these strategies also offer greater opportunities for failure of at least one repository. Is the advantage associated with either a multiplicity of sites or methods of disposal sufficiently pronounced to be reflected in the criteria for adequate protection of the environment?

PRESENT VERSUS FUTURE RISKS

The EPA has concluded from the Workshop participants at Reston and others that our society feels a strong obligation to protect future people from being harmed by the radioactive waste we have produced. It is not yet clear, however, and is a matter that could significantly affect the environmental protection criteria, what the relative importance should be of risks which may be incurred by present or future generations. Several issues which arise in this regard need elaboration.

Perhaps the most significant questions here concern the length of time within the terminal phase of disposal that should be addressed by the criteria and standards. Projections of potential environmental impacts become increasingly nebulous, and perhaps meaningless, as the time frame of interest lengthens. Should the criteria and standards address only a selected period of time? What should be the basis of such a selection: decline of the potential hazard due to radioactive decay? other natural processes? or social considerations? For purposes of discussion which would be the best selection: 100 years? 200 years? 500 years? 1,000 years? much longer than 1,000 years? Should a selected time period be significantly different for high-level waste, for spent fuel, or for TRU waste (assuming they were to be placed in a deep repository)? Behind all these questions is the increasing uncertainty that institutions will be able to react protectively to any problems which may arise over longer time periods.

It may be helpful here to ponder two views that are nearly opposite. One point of view holds that the risk of exposing future generations to radioactive waste releases should be minimized at almost any cost. Included in such acceptable costs would be much higher economic costs and the increased risks of exposing present populations (the benefactors of waste-producing activities). For high-level waste, holders of this perspective might argue for increased consideration of extraterrestrial disposal as opposed to geological disposal.

A divergent point of view is that almost no reasonable assumptions about the evolution of the human race lead to valid arguments for protecting future generations more than near-term generations. Indeed, the potentially improved technology of future generations could indicate designing some retrievability into the waste repository, to allow future generations flexibility to improve the management of the wastes. Conversely, if the human race retrogressed, adequate sealing of the repository (not necessarily incompatible with limited retrievability) would minimize the chances of human-caused intrusion.

As noted above, there is a spectrum of other potential perspectives between these two. What guidance should the criteria provide on this issue, if any?

SUMMARY OF CONSIDERATIONS

Certain issues have been discussed that have arisen during the continuing effort of the EPA to develop environmental protection criteria for the disposal of radioactive waste. Many of these were stimulated by the reports produced at the Reston Workshop or were too detailed or technical in nature to be addressed at that forum, whose primary purpose was to discuss very broad issues. Resolution of these matters, which in some cases are in the form of apparently contradictory but advantageous requirements, should be of interest to us all. The EPA therefore looks forward to receiving the benefit of the consideration of these issues by participants at this Workshop and has prepared the following list of questions that the participants may use to focus their deliberations.

Unplanned and Accidental Events

1. If the EPA addresses unplanned events in its environmental protection criteria, what would be an appropriate and effective approach? What aspects of the disposal process and of the unplanned events should be addressed?

Institutional Controls and Retrievability

1. Does the widely endorsed belief that disposal of high-level waste should be independent of the existence of future institutions necessarily imply foreclosure of "perpetual care" and remedial actions?
2. Should the environmental protection criteria require, encourage, discourage, forbid, or disregard monitoring or retrievability of the waste during the terminal phase of disposal?

Perspectives

1. Is it ethical to require high-level waste disposal technology to achieve goals that cannot be achieved for disposal of other forms of radioactive wastes?

2. Conversely, is it ethical not to require for other types of waste the same goals as may be set for high-level waste?
3. How might the EPA relate its activities regarding radioactive waste to the efforts of itself and others to control other pollutants?

Multiplicity

1. Is there a net advantage associated with either multiplicity of sites or methods of disposal sufficiently pronounced to be reflected in the criteria for adequate protection of the environment?

Present Versus Future Risks

1. Should the criteria and standards for high-level waste address only a selected period of time? What should be the basis of such a selection: decline of the potential hazard due to radioactive decay; other natural processes; or social considerations?
2. For purposes of discussion, which would be the best selection: 100 years? 200 years? 500 years? 1,000 years? much longer than 1,000 years?
3. Should the selected time period be significantly different for high-level waste, for spent fuel, or for TRU waste?
4. What guidance, if any, should the criteria provide on the relative concern for risks to present (or near-term) generations and to future generations?

TOPIC 1 GLOSSARY

Aquifer - A subsurface formation or geological unit containing sufficient saturated permeable material to yield significant quantities of water.

Deep Geological Disposal - Emplacement of wastes within or underneath appropriate geological formations, usually at depths of thousands of feet.

High-Level Waste - The highly radioactive liquid or solidified derivatives of that liquid that remains after reprocessing reactor fuel elements. The term may include spent fuel elements if they are discarded without reprocessing.

Leaching - Subjecting a material to the action of percolating water or other liquid that removes or separates soluble components.

Monitoring - A routine program to measure the quantity of the discharges from a waste disposal operation and their impact on the surrounding region, or to measure changes in other physical, chemical, or biological characteristics of the site.

Reprocessing - Chemical processing of irradiated nuclear reactor fuels to remove desired constituents.

Shallow Land Burial - The emplacement of wastes in the earth's crust, usually within 50 feet of the surface.

Tailings - The portion of ore remaining after a mineral has been extracted.

Terminal Phase of Disposal (Disposal Phase) - Period of time which follows a determination that the repository is functioning satisfactorily. No further activities other than monitoring (possibly) are envisioned.

Transuranic Elements - Elements with a mass number greater than 92. They include neptunium, plutonium, americium, and curium.

Transuranic Waste (TRU) - Wastes known or assumed to contain more than a specified concentration of transuranic elements (presently 10 nanocuries of alpha emitters per gram of waste).

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POLICY AND TECHNICAL CONSIDERATIONS FOR HIGH-LEVEL RADIOACTIVE WASTE

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It is now clear that there is a national resolve to move forward with facilities for the long-term management of nuclear wastes. This is a national program, presently involving a number of government agencies whose assigned functions are distinct, but in fact require a close degree of cooperation for the fulfillment of this national commitment. The Environmental Protection Agency (EPA) has responsibility for setting generally applicable environmental standards, and specifically in this case for radiation in the environment that may result from management of high-level nuclear waste. The Energy Research and Development Administration (ERDA) is assigned research and site development responsibility, and the Nuclear Regulatory Commission (NRC) is assigned the licensing of these facilities.

Thus, in a general sense, when we are discussing the subject of this session, "Policy and Technical Considerations for High-Level Radioactive Waste," we are discussing the responsibilities of all the concerned Federal government agencies and not just those of the EPA. The development of high-level waste management systems is not different from the development of any management system. It is a process of delineation of objectives, resources, technical knowledge base, priorities, comparison of possible outcomes of strategies, and placing of bounds on the unknown in your analysis.

As a participant in the EPA Reston conference in February 1977, I was concerned for the attendees who were interested in waste management but did not have an intimate knowledge of radiation or of waste disposal concepts. They were being asked for input on waste management objectives and priorities without being briefed on one of the important factors in a management plan, i.e., an understanding of the existing technical knowledge base. For example, the EPA Issues and Objectives paper for these sessions asks that attention be focused on questions such as, what should be the relative risks which may be incurred by present or future generations?" Another question that is posed is, how long should the standards and criteria apply?" As a technical person, I would rephrase the questions to: "Do any of the present calculations show that there are significant risks to future generations?" and "Does the present analysis predict special problems that are time-dependent and require different standards and criteria?" Such a technical knowledge base does exist and I believe that the attendees here who wished to help formulate the government's

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waste management program from the perspective of societal goals and policy would have been better equipped to participate if a summary of this knowlege base had been made available to all attendees.

This problem is indicative of one kind of policy issue in waste management. Public policy flows from public perception of issues and there is today, in my belief, a mistaken public perception that the technical community is starting from a very small knowlege base and really does not have answers on waste management. The contrary is true. The technical knowledge base is present and ready for use. Again, if the public does not have this perception, then confidence in Federal agencies (who have this responsibility) is lacking, and all of this results in one of the country's policy and institutional issues that must be faced and resolved in the management of waste.

I would like to first focus on the technical knowlege base that does exist for geological disposal of high-level and transuranic (TRU) waste and draw some conclusions on important issues for their management. The Reston conference indicated that there can be agreed-upon, acceptable, broad, generally applicable criteria for all waste disposal. Then, in keeping with the EPA goal of setting specific standards for high-level waste, it is necessary to place bounds on what may be the range of possible long-term environmental effects from geologic disposal, and clarify if there is a problem for the present and future generations. From what we now know, it can be concluded that:

1. The decision to use geologic disposal has significantly narrowed the possible range of adverse effects on people and the environment.
2. For geologic disposal concepts, many scenarios have been analyzed for modes of the release of radioactivity from the formations and these demonstrate that the radiological effects on the environment and people are minimal.

The use of geologic disposal creates a number of barriers between man and the highly radioactive materials. This method of disposal can provide favorable combinations of: (1) geologic formations that have demonstrated stability in the range of millions of years; (2) distances from underground aquifers; and (3) good ion exchange with media outside of the formation of interest to trap radioactive elements that may have been accidentally released. Additional barriers can be provided by the waste being in a matrix with low leachability and in a chemical and physical form of the radioactive elements that have a minimum radiological significance to man. It is important to realize that there is no requirement that all of these barriers function perfectly for satisfactory isolation. Any one or an effective combination of these barriers essentially removes the need of long-term management of waste by active human management systems which in turn eliminates a dependency on stability of governments for waste management.

In the extreme, even some release of radioactive materials from repositories is not necessarily bad. The mere existence of radioactive materials in the environment does not mean that man or the environment is being harmed. Nor does the fact that some radioactive materials have long half-lives directly correlate to a danger to man. For example, most of the residual radioactivity for which we are concerned over long periods of time, i.e., greater than 400-600 years, must either be breathed in a very fine particulate form or ingested before there is significant harm to an individual. Thus, radiation protection criteria do not call for zero quantities of radiation in the environment to be deemed safe.

Research initiated by the National Academy of Sciences, more than twenty years ago, has technically demonstrated that at least one medium, salt, has the desirable features for isolation of high-level and TRU wastes. ERDA, through the Office of Waste Isolation (OWI) (Ref. 1) at Oak Ridge National Laboratory has programs in progress to select particular salt formations that meet the desirable site factors that have been identified from this previous research. The site factors describe the physical characeristics of the formation such as the size of the formation, the purity of the salt, the proximity to underground aquifers, the seismicity of the area, and the type of surrounding soil and overburden. Those studies indicate that criteria for waste disposal, not identified as criteria but as factors (Ref. 2), are being formulated and used in design considerations. Similar studies in progress on other geologic formations include shale, crystalline rock, limestone, and others, but more detailed data is available on salt.

From these site factors which are already being used in engineering design considerations for salt repositories, many analyses of possible long-range impacts to people have been done. One such study (Ref. 3) concludes that, during the operational phase of a repository, the only time-period when radiation is likely to be released, the dose commitment from the total wastes in a repository to an individual located very nearby is only a few thousandths of one percent of the radiation that one receives annually from natural radiation.

Although the expected releases during the operational phase are very low and appear to be insignificant, the EPA may wish to apply their approaches to radiation standards that were used in the development of Part 190 of the Code of Federal Regulations, for the Nuclear Fuel Cycle. A numerical value selected in a similar fashion to the allotment of 25 man-rem/year, out of the generally accepted guidance of 170 man-rem/year, to an individual would be an acceptable approach to the setting of a standard for the operational phase. However, if repositories performed as they are designed, and there is no reason to believe they will not, there will be nothing in a radiological sense to monitor after the operational phase of the repository. It certainly doesn't then seem desirable to require monitoring, even through such mechanisms as special wells, because the integrity of the formaton could be violated and defeat the main objective of isolation.

It appears that the only mechanisms that could cause a release of radioactivity fall into the categories of unplanned events or accidents. As was discussed in the EPA Issues and Objectives paper for this topic, the probabilities and consequences of unplanned events are not amenable to monitoring, especially after the operational phase of the repository. However, I believe that it is proper for the EPA to assess the consequences of unplanned events and accidents to clarify the probable bounds of any long-term risks.

The related technical and policy questions to EPA guidance to other Federal agencies in addressing accidents are: how to describe what EPA determines as a set of acceptable impacts which cannot be measured or called a standard in the usual sense of the word; and how to translate this set of acceptable risks into meaningful information that ERDA can use to compare the effectiveness of geologic isolation. In the following discussion, I will describe some of the characteristics of what I will call EPA's "unusual standard" and how it should and should not be applied.

1. The "unusual standard" should be framed with enough clarity in order not to invite legal challenges to EPA in meeting its responsibilities under the National Environmental Policy Act (NEPA) for waste disposal and, thereby, cause a delay in this country's programs for waste disposal.
2. The "unusual standard" should avoid a specificity so that it could not be confused with design specifications for the site, or design specifications for waste packaging, or other functions that are considered as engineering design. If this specificity is not avoided, not only would EPA be exceeding its proper role and responsibilities, but there could be resultant policy complications in the Federal interagency responsibilities of EPA, ERDA, and NRC.
3. The "unusual standards" should view possible future risks from the reasonable man concept and set general guidelines. They should not attempt to minimize risks to man or the environment or to reach the optimum design of a repository. The "unusual standard" should identify what EPA considers an acceptable level of achievement for a site-repository design combination. The extent to which any repository would achieve results beyond the acceptable level

should properly be left to ERDA in performing its programmatic functions and NRC in its regulatory functions. For example, the optimization of a repository design will be achieved through detailed engineering and from the base of experience gained in the early operational phases.

4. The methodology of pathway modeling for relating the EPA's "unusual standard" to site-specific characteristics should be uniformly agreed upon by all cognizant Federal agencies.
5. The goals of geologic isolation are met if only one or more of the many features of isolation are functional to assure the long-term safety of man and the environment from radiation releases. These features include stability of the formation, no contact with transport media such as air or water, good ion exchange with soils outside of the media to trap the radioactive elements, and physical and chemical forms of radioactive elements that limit their possible effects on man. EPA should consider using these features as a group of weighted multipliers to form what could be called an isolation index. If, by analyses, the EPA could select a reasonable isolation index from various combinations of isolation features to achieve acceptable long-term risks, ERDA would have the freedom to determine how to match and optimize the specific features in the isolation index with the realities of a particular site and geologic formation while meeting the broad guidelines of the EPA. Thus, the isolation index could be a functional way of relating what are considered as acceptable risks by the EPA to the specific design considerations that ERDA may be using.

Again, I believe that there is a technical knowledge base to select the EPA "unusual standard." The supplements (Refs. 4, 5) to "Environmental Survey of the Uranium Fuel Cycle" summarize the results of numerous calculations that are applicable to such an analysis by EPA. In my opinion, the projected dose to individuals and general population in these analyses show that the potential radiation impact already falls within the variations of possible impacts to which people are exposed from natural radiation in our environment.

The only kinds of events that caused significant releases of radiation were low probability disasters. For example, one case showed that a direct hit on the repository area by a large meteor of at least 2 km in diameter would be necessary to cause a severe disruption and radiation release. The immediate consequences of this kind of event, even forgetting the low probability, would far outweigh any long-term radiation impact. From the present information base, I believe that the EPA, using the "reasonable man" concept, now could select those accident analyses that may be used to draft acceptable "unusual standards" and develop an isolation index suitable for use by ERDA and NRC in developing geologic disposal sites for high-level and transuranic waste.

In closing, I would like to emphasize an important point that was made by Dr. Margaret N. Maxey, Associate Professor of Bioethics at the University of Detroit, at the Reston conference. She pointed out that it is very important to use relative risk analysis along with customary risk-benefit analysis. For example, the types of scenarios designed especially for intrusion considerations that may result in radiation releases from repositories causing harm to man are theoretically similar to those where man may intrude into large deposits of naturally occurring toxic elements and chemicals from the earth, such as cinnabar, radium, or chromium. Thus, if we focus--as we properly should--on the relative risks involved, it helps to place these unplanned events and accidents in repositories in proper perspective. Neither should we let terms such as "long half-lives" create biases and fears because stable elements have infinitely long half-lives. These naturally occurring toxic elements are present and will be forever. Accordingly, when standards based upon accidental events are considered by EPA, these relative risks should be taken into account.

Finally, I believe that there exists a knowledge base today from which EPA can set generally applicable criteria and standards for the geologic waste disposal of high-level and TRU wastes; that the standards set by EPA should define what is acceptable, and not attempt to define the optimum achievable result in site selection and repository design; that EPA can formulate an acceptable waste isolation index that bridges their standard to the guidance needed by ERDA; and that these EPA general standards should not infringe either on ERDA's flexibility in achieving its programmatic goals within these EPA criteria, or on NRC's regulatory responsibilities for licensing.

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CONSIDERATIONS IN ESTABLISHING CRITERIA FOR NUCLEAR WASTE FACILITIES

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I would like to first thank the organizers of this Workshop for the opportunity to participate in these sessions to discuss criteria for the disposal of radioactive waste. In Michigan, we have been concerned with this issue as we are presently working with the Energy Research and Development Administration (ERDA) on a procedure for establishing criteria which will be used in the selection of repository sites. Thus, any insight that can be gained through this Workshop will assist me in these negotations.

As a part of our studies in Michigan, we were asked by the Governor to hold a series of public meetings to obtain citizen-input on site selection criteria. It is clear from these meetings that the task being undertaken at these Workshops is a most difficult one. Most of the citizens that testify at our hearings believe that the only valid criterion is one which will absolutely prohibit the location of a repository in their area.

The most difficult part of this process of establishing criteria appears to be that of obtaining significant yet reasonable public involvement. If this problem cannot be resolved, then I foresee the program for the disposal of nuclear waste moving in one of two directions, neither of which is desirable. One choice is to conclude that the public is either unable or unwilling to participate in the process of site selection, and base the selection on technical criteria alone as best determined by the scientific community. The second choice is to conclude that the scientific community is unable to present the alternatives in terms which facilitate public decision making, and base the selection on political criteria alone.

There are already many members of our legislature who have reached this second conclusion. Legislation has been introduced which would require site approval by a majority vote of both houses of the state legislature. Based on my conversations with members of the legislature, this may well have the effect of eliminating all sites in our state. Thus, the political decision will probably result in continued storage of spent fuel cells in surface containers at the nuclear powered generating plants. This may well be the least acceptable solution from a safety viewpoint, but it avoids the tough issues

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we are facing here at the Workshop. With this solution, it is not necessary to reach a consensus on siting criteria.

Assuming, however, that society will not elect to bypass the issue, I would like to comment on some of the issues that have been identified in the resource paper prepared for this Workshop.

UNPLANNED ACCIDENTAL EVENTS

While environmental criteria for a nuclear waste repository should deal primarily with routine release and emissions of radioactivity under normal operating conditions, there exists the possibility of various unplanned and accidental events. I believe environmental criteria should consider these possibilities as well, because the impact of these unplanned events may be drastically different for alternative sites.

If the criteria were limited to the expected levels of routine discharges, a site located in a dry environment and one located adjacent to the Great Lakes might be rated equal. However, if there were a sudden discharge due to an accident, the results could be quite different. At the second site, the radioactivity could reach the Great Lakes and be transmitted to many of the major population centers in the eastern United States. Since the impact of such an occurrence would be catastrophic in one case, and could possibly be contained in the other case, the criteria should not be equal. To argue that we should merely increase the criteria on the critical site to the limit we find acceptable on the safer site is not an acceptable resolution, as it is a contradiction of facts.

We must resolve the difficulties associated with combining nonsimilar statistics if we choose to include both planned and unplanned events in the same criteria. That means we must agree that an event with a probability 1×10^{-x} and severity $y \times 10^{-x}$ is equal to an event with a probability of $1 \times 10^{-x/2}$ and severity $y \times 10^{-x/2}$.

Acceptable levels of routine releases of radioactivity will presumably reflect the moderate-probability, low-risk situation while unplanned and accidental occurrences will reflect the low probability, high-risk situation. Since certain improbable events could result in massive releases of radioactivity regardless of facility design, some resolution must be reached on how these two situations are combined into a single criterion.

In fact, this may require the combination of several different representations of unplanned events. Natural occurrences, such as meteorological and geological events, may have one range of probabilities and risk. Technical failures, such as equipment accidents and fires, may have another range, and unplanned occurrences related to human intrusion may have a third range of probability and associated risk.

RETRIEVABILITY

If containment integrity is not severely compromised by retrievability in the terminal storage phase, there are two factors which make this option desirable. The first is that if on-and near-site monitoring indicate excessive radiation release or the potential for such release, corrective action may be more readily accomplished. The second factor is that in the event of a presently unavailable technological development, such as transmutation, access to the waste material without great expense or difficulty would be advantageous.

Perhaps the resolution of this issue lies in defining a specific time period for which retrievability is assured, and requiring additional institutional controls during this time. While it is difficult to conceive of institutional controls promulgated to cover the 250,000 years required for the radioactivity to decrease, there is precedent for institutional controls measured in decades. For example, one might consider criteria that require retrievability for the expected life of fission reactors as a major source of electrical energy. The projections I have seen place our known supplies of uranium at 40-60 years. If we are to dispose of spent fuel rods, as it appears from President Carter's policy statement last week, it might be reasonable to require that they be retrievable for this same 40-60 years.

However, there exists a need for more information on the issue of retrievability and repository design. If there is a direct positive relationship between the degree of retrievability and the potential for containment failure or intentional human intrusion, then the benefits of retrievability may not be sufficiently large to outweigh the hazards.

At the very least, guidelines developed by EPA and others must recognize the need for more stringent institutional controls during any period of easy retrievability.

MULTIPLICITY

The value of retrievability would be only partially realized unless this is associated with multiplicity of sites and/or methods of waste disposal. In Michigan, our task force on nuclear waste disposal recommended that development of a waste repository in that state be contingent upon concurrent development of a repository in another state. With the cost of a repository with sufficient capacity to store the anticipated volume of high-level waste to be produced in the next 25 years estimated at $300 million, or only about 3 percent of the annual output from the nuclear industry, this appears to be a small price to pay for insurance against a single site failure.

However, determination of the desirability of this program feature is primarily one of economics. Unless it can be argued that multiplicity will permit the lowering of environmental criteria related to public health, environmental criteria should apply primarily to the potential impacts of operation of a given facility rather than the program as a whole. I believe the public is entitled to assurance that each facility, in and of itself, can meet acceptable potential radiation release criteria. Thus, I am not convinced that multiplicity should be considered in establishing environmental guidelines.

PRESENT VERSUS FUTURE RISKS

As discussed under the section on retrievability, there may be a legitimate basis for differentiating between criteria applicable to the short-term (40-60 years) and the long-term storage of high-level radioactive waste. However, this is based on the fact that the operation would differ significantly, not on a conscious choice to differentiate between protection of present and future generations. I can find no moral basis for favoring one generation over another in the setting of criteria.

The real trade-off between generations may be related to the distinction between a low-probability, high-risk event associated with a future accident, and a moderate-probability, low-risk event such as leakage which may affect present generations. Perhaps in considering this trade-off we should not utilize the product of the probability and the risk as a criterion, but utilize each one separately, that is, establish a maximum risk we are willing to accept independent of the probability and vice versa. In the short term, the probability factor may govern, and for the long term the risk factor may govern.

This is an accepted practice in an area of far greater danger to society--that of highway safety. Most states utilize a combined rate-number method for identifying highway locations for priority treatment. If the rate (or the probability of involvement) exceeds a specified criterion, the location is singled out for corrective treatment. Alternatively, if the number of accidents exceeds a different specified limit (a measure of the risk associated with the location) the need for corrective treatment is indicated. Parenthetically, it might be noted that this procedure did not evolve from a series of public hearings and public acceptance of the policies. However, the procedure has been upheld by the courts as legitimate public policy.

PERSPECTIVES ON SAFETY

This last example forms the basis for a final comment on the issues raised in the Issues and Objectives paper--that of the relative goals we are willing to accept in various aspects of our lives.

It seems to me that there may be two acceptable approaches to this problem. One approach would be to utilize life-cycle accounting as a basis for comparing alternatives. In this approach the probable risk to society from the entire nuclear fuel cycle would be compared with alternatives using coal, solar or other renewable resources, and with doing without the energy. The risk from the nuclear fuel cycle would then have to be brought below the alternatives to be acceptable. Thus, if the risk associated with the production of nuclear energy is lower than the alternatives, we might accept a higher risk associated with disposal.

Another alternative is to establish criteria to assure society that the risk from a nuclear facility is less than that of other technologies they have already accepted. This may not provide an immediately acceptable standard, as the public acceptance of the automobile is evidence that society will voluntarily accept a higher risk than government is willing to impose upon them.

It should be obvious from these comments that I am not prepared to specify criteria, or even to expound completely developed theories on these issues at this time. I am confident that I will have a clearer perspective by Thursday, and I hope we all will share in this step in the continued development of safety criteria for the siting of radioactive waste disposal facilities.

RADIOACTIVE WASTE: THE GIFT THAT NEVER STOPS GIVING

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For over thirty years the nuclear community--the U.S. Government and the private nuclear industry--has delayed seriously addressing the problem of disposal of radioactive wastes generated by both the military weapons program and the civilian nuclear power program. Now, quite suddenly, there seems to be a rush to get on with the job, to find solutions to the radwaste management problem that will be acceptable to and accepted by the public. This flurry of activity is undoubtedly in part a result of political pressures. The defeat of the test case for nuclear "energy parks" in Pennsylvania in 1975 was political, and the waste issue was an important factor in the overwhelming public rejection of energy parks. The vote in 1976 nuclear power initiatives in several states, though they were political defeats for nuclear opponents, made it clear that about one-third of the electorate in those states was deeply concerned about unsolved issues involving the use of nuclear power--and radioactive waste management was again a major issue. Lastly, the demise of the Joint Committee on Atomic Energy should serve notice on the nuclear community that the public and Congress are far more aware of the problems of nuclear power--and again especially of containment of radioactive wastes--than would have been imagined a scant two years ago. Furthermore, informed members of the public are well aware that the promises of safe, clean, cheap nuclear power made twenty years ago have not materialized, and that the nuclear fuel cycle problems of twenty years ago have not been solved.

Two of these unsolved problems of the nuclear age are the subject of this meeting: first, the disposal of the radioactive wastes of the commercial and military nuclear industries, and, second, how large a radiation dose to prescribe for the public--present and future--from the waste disposal techniques adopted. For many citizens, these two issues are the crux of opposition to nuclear power. Our discussion in this paper will address selected aspects of these two problems as they relate to the public policy decisions that will result from this EPA rulemaking procedure.

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Since the birth of the nuclear industry, wastes have been allowed to accumulate with insufficient attention paid to either their ultimate disposal or the effects of radiation on man. While many storage and disposal schemes have been put forward as solutions to the high-level waste problem, there does not appear to be a consensus among scientists outside the nuclear community that appropriate technology has been developed to truly "solve" the problem. Indeed, a comparison of the articles in a 1976 symposium on radioactive waste (Ref. 1) with those in a 1959 Congressional hearing (Ref. 2) suggests that little progress has been made in the intervening years toward developing better chemical binding media for high-level wastes, or identifying suitable geological formations other than salt strata which have been assumed to be suitable. Extraterrestrial disposal and tectonic plate disposal have been proposed, but there seems to have been no real consideration of the possibility or practicality of direct disposal of spent fuel rods until last week. Many feel that much more data on geologic stability and chemical binding to prevent migration should be collected prior to to making a final irreversible decision. But the high-level waste problems may be the easiest to solve because of the relatively small volumes to deal with.

The tailings piles from uranium and phosphate mining release only minute quantities of radioactive radon gas, but the volume of these low-level wastes is enormous--about 7.8 x 10^8 cubic meters is expected to be moved in uranium milling for nuclear power between 1975 and 2000 (Ref. 3). The sheer volume of the existing wastes may preclude any actions to lower the dose from the radioactive radon. However, the public health costs of doing nothing to prevent exposures are also prohibitive. The uranium mill tailings were recognized as a potential public health problem many years ago (Ref. 4). No progress appears to have been developed toward a real solution of the entire set of radwaste problems.

A look at the issue of radiation-induced health effects--i.e., what the effects are and how much radiation is required to produce them--reveals that precise and satisfying answers are simply not available. It is not, as sometimes claimed, because the necessary experiments have not been performed on human beings; many have been, on small groups, large groups, and whole populations. The tragedy is that the responsible agencies have adopted the policy of not collecting the necessary data from those group and mass exposures. For example, we are aware of no body of follow-up long-term health data for the U.S. servicemen who were ordered to march across radioactive ground shortly after an atomic bomb blast in the 1950's.* Nor have adequate data been collected on the health effects of doses received by the thousands of workers in the nuclear industry since its inception. And, of course, the health effects of fallout from atmospheric testing on U.S. and world populations are widely thought to be negligible only because the nuclear community says that they are negligible. The claim is not based upon rigorous analysis of appropriate health data.

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* See Appendix.

Between 1931 and 1958, the maximum annual exposure level for workers in areas of radiation decreased in stages from 60 rem to 5 rem. However, at no time was it possible to say that new lower levels represented safe levels. The same may be said about the annual exposure of 0.5 rem to members of the public: the permissible exposure has not been shown to be a safe exposure.

The importance of fully understanding the health effects of radiation becomes apparent when we consider the consequences of not fully appreciating them. If we underestimate the effects of exposure, as has been the historical practice, we in effect create a subsidy for the individual or institution adminstering the dose, and an unanticipated, undesired health cost for the recipient of the dose. When radiation dose effects are underestimated, the one delivering the dose is allowed to operate in generally a looser, often sloppier manner than would otherwise be permitted.

It seems evident that the former Atomic Energy Commission (AEC)-Nuclear Regulatory Commission (NRC)-Energy Research and Development Administration (ERDA) combine has been and is doing exactly that--consistently underestimating radiation hazards. And the manner in which they are doing this is particularly disturbing. For instance, in denying a rulemaking petition submitted by the Natural Resources Defense Council (NRDC), the NRC ruled that the "hot particle" hypothesis "is speculative and not supported by the body of data and knowledge on the subject." (Ref. 5). A moment's reflection on these criteria for rejection will confirm that few, if any, of the important scientific discoveries of the last few hundred years would have measured up for consideration at the time of discovery under these criteria. Clearly, the NRC must demonstrate that these criteria can be applied to any area of science without the suppression or elimination of data, information, and discoveries which do not conform to "the body of scientific data and knowledge on the subject."

In 1972, Bross (Ref. 6) showed that there were subgroups in the U.S. population which were up to an order of magnitude more sensitive to the effects of radiation than the general population. The NRC exposure regulations do not make allowances for such subgroups. Nor has the NRC, to our knowledge, ever tried to determine the possible existence of other more sensitive subgroups or to determine even the number of individuals in the already identified subgroups.

The Generic Environmental Statement on Mixed Oxide (GESMO) proceedings (Ref. 7) have revealed that, if there had been any doubts, the image of a conservative, well-regulated industry is a myth. Behind the facade of cleanliness and orderliness cultivated by both the industry and the NRC is an industry virtually out of control. Records show that workers are overexposed to radiation (Ref. 8). Yet when asked in the GESMO proceedings what would be the highest exposure to workers in model mixed oxide fabricating plants (Ref. 9), the NRC staff replied, *en toto*, "The radiation exposures to the highest exposed workers would be limited to 10 CFR Part 20 limits regardless of the conditions postulated" (Ref. 10).

At one plutonium fabrication plant in a two-year period there were incidents in which the airborne concentrations of plutonium exceeded the Maximum Permissible Concentration (Ref. 11). Yet, according to the NRC, the release of plutonium to the atmosphere can be considered proprietary information (Ref. 12).

One of the major criticisms of the AEC-NRC "Reactor Safety Study" (WASH-1400) has been that it seriously underestimated the effects of released radioactivity from reactor accidents (Ref. 13). This has occurred in two ways. The doses were underestimated, first, by ignoring the effects of certain released isotopes, and, second (Ref. 14), by omitting in numerous graphs the effects of cancer deaths which would occur long after the accident. For one postulated accident with a risk factor of 1 in 10,000 per year with 100 reactors operating, 10 fatalities were predicted. But the inclusion of long-term deaths from radiation-induced cancer would raise this figure to around 6,000 deaths.

The systematic underestimation of human radiation effects has military uses also. With dose effects underrated, it is then possible to convince the public that we can even survive and "win" a nuclear war. This, in turn, has encouraged us to indulge in bomb shelter construction and other civil defense fantasies. It has allowed the U.S. Government to spend hundreds of billions of dollars on the nuclear arsenal. It has led policy-makers to seriously suggest the use of tactical nuclear weapons in limited warfare. *Only* by underestimating the effects of ionizing radiation on man could any form of nuclear war be considered possible. And in the process of developing the massive "nuclear shield, we have also created the present bulk of our radioactive waste problem.

In a few ways the storage of radwaste may be said to have improved slightly. It is assumed that we are no longer dumping hundreds of curies annually of cesium-137, strontium-90, and rare earth isotopes into White Oak Creek (Ref. 14), or that a curie or two of iodine-131 is released to the air daily at Hanford (Ref. 15). But we recall the leakage of 115,000 gallons of liquid high-level radwaste in 1973, and the 1976 findings of plutonium migration offsite at Maxey Flats, as well as pilferage from the Beatty, Nevada, low-level waste storage site. These incidents tell us that we should have done the job of waste disposal right in the first place. The costs of redoing the job will, of course, greatly exceed the initial costs. The lesson is clearly that economically expedient but inadequate methods of radioactive waste disposal are the wrong way to handle the problem. The health consequences of failing to do what must be done are societally unacceptable. Leaving these decisions in the past to those individuals and agencies that deemed themselves "expert" and "responsible" has been a most serious error that the public does not intend to repeat.

Let us consider a specific example of the problem relating to high-level waste management to exemplify how well the task must be done. Consider a geologic depository which remains intact for not a mere thousand years, but for a thousand times that length of time, a million years. It seems difficult enough to get a high degree of certainty from geologists on integrity for a few thousand years; adequate predictability for a million years seems clearly beyond the state of the art. Our geologic disposal site should probably be chosen with attention to the low value of its mineral content, such that it will have a low probability of future attractiveness for mineral extraction. The possibility of liquid injection, however, poses another uncertainty. At present, it is estimated that more than a billion gallons of oil-field brine and industrial waste are pumped underground in the U.S. each day (Ref. 16). It would seem prudent to discourage such future use of this site for liquid disposal. How ironic if a future generation purposely, or accidentally, injected water into say, our carefully selected dry salt deposit.

Now, after the million intact years we are assuming, let us suppose that the repository begins to leak, just a little, so that it takes a second million years for the contents to get out. This is well within the time ranges to be expected from glassy waste forms being proposed with leach rates on the order of 10^{-7} grams per square centimeter per day.

What, then, are the consequences of this scenario for only one isotope: iodine-129? The total inventory of fission products to be accumulated by the year 2000 has been estimated by Blomeke and Bond (Ref. 17) to be approximately 100 billion Ci. Of this, approximately 7,000 Ci will be iodine-129, an amount close to the EPA estimate of 1973 (Ref. 18). To simplify matters, consider that these 7,000 curies become uniformly diluted in the stable iodine of the biosphere. We estimate that there may be as much as 100 billion metric tons of iodine available to the biosphere. This defines a steady state concentration diminished only by radioactive decay. The iodine content of a standard thyroid is 7 milligrams (Ref 19). From this, the activity in a standard thyroid can be found, and in turn, using the methods of the International Commission on

Radiological Protection (ICRP) Publications 10 and 2, the dose is obtained (Ref. 20). If the world population is assumed to remain at its present number of 4 billion, the total dose is 127 person-rem each year to the thyroid initially. If this is summed over the total decay of the iodine-129 the result is 3 billion person-rem to the thyroid. Following the method of EPA (Ref. 21) which uses the linear non-threshold procedure to estimate cancer risk based on the Biological Effects of Ionizing Radiation (BEIR) report (Ref. 22), a total of 30,000 to 40,000 thyroid cancers is estimated. At current rates 5,000 to 10,000 of these cancers would be fatal. These health effects are greater than those estimated by EPA for the industry through the year 2020, assuming current release practices for iodine-129, tritium, krypton-85, and actinides. This EPA estimate is about 10,000 health effects, with about 6,500 fatalities (Ref. 23). Thus, the total health cost of nuclear power and weapons programs would be about doubled. It would seem appropriate to remember this when comparing the effects of nuclear power plants to those of fossil-fueled plants.

The estimate of 30,000 to 40,000 health effects from the iodine-129 escape assumes that the BEIR estimates are valid. Recently, as part of the NRDC testimony in the GESMO proceedings, Tamplin and Cochran have shown that, based on the Mancuso study, (Ref. 24), the BEIR estimates of cancer are 18 times too low. In this case, the toll might well be 500,000 to 750,000 thyroid cancers, with about 100,000 fatalities. If these estimates seem an exercise in fiction to some, we suggest that the BEIR estimates were similarly received by some less than a decade ago. Clearly, again, the more we learn about the effects of radiation on people, the more serious they become. Thus, what may appear to be excessive conservatisms in numerical standards today may well appear criminally negligent rashness tomorrow.

The economic impact derived from these calculations utilizes the total exposure estimate of 3 billion person-rem to the thyroid and the NRC figure of $1,000 per person-rem. The health costs equal some 3 trillion dollars, in current dollars, or about twice the current U.S. gross national product. It is an amount far in excess of the total cumulative expenditures to date on the radwaste problem. If present society chooses an "economically feasible" solution now, it is clear that the full costs are merely deferred.

If we consider a continuing monitoring of the geologic repository to be a socially desirable caution, and assume that it might be prudent to continue keeping an eye on its integrity until the health effects of the isotope iodine-129 are reduced by, say, eightfold, the monitoring must be undertaken for three half-lives of the iodine-129, or 51 million years. In current dollars, a modest monitoring program with only three employees would cost $40,000 per year, or a total of 2 trillion dollars, again greater than our current GNP.

There is an alternative to geologic disposal. Iodine-129 has a fairly high neutron capture cross section. If a dummy fuel rod were filled with a suitable iodine-129 compound and irradiated in a typical commercial light water reactor, the rate of reaction would be about 2 percent each year. This is not beyond technical feasibility. Partitioning of wastes has been considered at Oak Ridge (Ref. 25) and at Hanford (Ref. 26), among other studies. We have considered here only the isotope iodine-129. It is not at all clear to us, therefore, that the wisest course of action will be the anticipated irretrievable geologic disposal of solidified high-level waste in bedded salt.

We turn next to what must be considered an example of the inaccuracy and inadequacy of agency calculations of dose commitment with respect to radiation-induced health costs of future generations, viz., the dose calculations submitted by the NRC staff in its GESMO statement. It is suggested therein that the annual lung dose to the public from the uranium mill tailings piles will be 1.6×10^4 person-rem, assuming no plutonium or uranium recycle, and 1.3×10^4 person-rem with recycle of plutonium and uranium (Ref. 27). The difference between these numbers is vanishingly small compared with the errors in both numbers.

According to the Final GESMO (Ref. 28):

> The calculated dose represents the dose which would be received by an individual or a population which moved into a plant vicinity during the final year of plant operation, resided in the vicinity for one year, and then moved. In this sense the dose represents the dose received from one year's activity (breathing, eating, etc.). However, the doses include a future integration over the next 50 years of life from any isotope taken into the body which will continue to reside in the body even after intake has stopped. Thus, the calculated internal doses are 50-year commitments which result from a one-year exposure.

This dose to the lung is calculated using a model designed to minimize the effects of radiation to the critical areas of the lung. For the purposes of this discussion we embrace the admonition of the EPA (Ref. 29):

> One concerned with radon exposure is aware of past failures to provide adequate protection and has reason to be conservative in any value judgments and assumptions he is forced to make concerning radon dosimetry.

We thus use the lung model used by the EPA which produces estimates of lung doses 100 times that of the NRC. This choice introduces a factor of 100 error in the NRC dose.

While stressing the "conservative assumptions," those which tend to overestimate doses and effects, the NRC (Ref. 30) considers

> ...the extremely unlikely situation of an individual residing 500 meters from an operating facility and eating all his food produced at this location....

It is difficult to assess the numbers of people who grow all their own food in the uranium mill towns of the west, but of the 12 tailings piles in Colorado in 1971, 9 were within 2 miles of a town; in Durango (population 10,000) and Gunnison (population 5,000) they are adjacent the town, and in Grand Junction (population 20,000) at the center of the city (Ref. 31). It is doubtful that Colorado is unique in having towns in the vicinity of tailings piles.

It is also noted by the EPA that in buildings with poor ventilation rates, the radon daughters build up rapidly with a rapid increase in dose. The rise can be by a factor of up to perhaps 50. For people who live where winters are cold, it is not necessary to emphasize what poor ventilation means. It means a warmer house. Considering the populations near the tailings piles in Colorado not to be unique, and the population densities considerably higher than those used in the Final GESMO (Ref. 32), we suggest a factor of 10 more to contribute to the dose. It should be noted that there are no assurances coming from the NRC that the mistakes of the past will not be repeated, let alone be acknowledged. There seems to be little to prevent future populations from building homes and towns near or even on top of future tailings piles. Indeed, it is not difficult to suggest that the towns of Durango, Gunnison, and Grand Junction now receive the population dose the NRC calculates for the entire country in the year 2000. And Colorado now represents only about 6 percent of the U.S. milling capacity.

The Final GESMO does admit to a small underestimation of the dose (Ref. 33).

> Though these risk estimates are the upperbound estimates given in the Rasmussen Report Reactor Safety Study, Appendix VI, higher estimates can be developed by the use of the "relative risk" model along with the assumption that the risk prevails for the duration of life. This would produce risk values up to sevenfold greater than those used in GESMO.

We accept the factor of 7 increase in cancer risk simply by using a different model for estimating risk.

We now come to the thorniest aspect and the largest source of error in the Final GESMO tailings piles calculation. It assumes, as already mentioned, only one-year exposures to the radon emissions and calculates none whatsoever beyond the year 2000. With total disregard for the calculational methods of the NRC, the tailings piles keep on emitting radioactive radon gas. At the time the NRC stops calculating the population dose, over 99.995 percent of the thorium-230 has yet to decay and release its radon gas.

The problem now breaks into two parts. First, for how long into the future do we estimate health effects, and, second, what level of population do we assume for this period? To answer the first, we use the mean life of thorium-230 of 120,000 years as the period of calculation. We acknowledge our total inability to derive meaningful population estimates for the upcoming 120,000 years. But we also must reject the NRC projection of zero population dose after the year 2000. The Environmental Protection Agency appears to use a constant population in their 100-year dose estimation (Ref. 34). We feel this is also an arbitrarily short cutoff. For want of any better or more justifiable population estimates, we will assume a constant population. It must be emphasized that the long term success of technology may allow the earth to carry a much larger population than we now know. On the other hand, our reliance on technology to solve the problems of mankind may fail, and a much smaller population may then result.

To calculate the number of lung cancers, which are virtually always fatal, we will use the cancer estimate given by the NRC in its Final GESMO document of 22 lung cancers per million person-rem which yields, when all the error factors we use are brought together:

$$1.6 \times 10^{4} \frac{\text{person-rem}}{\text{year}} \times 100 \times 7 \times 10 \times 120{,}000 \text{ years} \times$$

$$22 \times 10^{-6} \frac{\text{lung cancers}}{\text{rem}} = 3 \times 10^{8} \text{ cancers.}$$

As large as this number is, it is neither the only gross calculational error nor the largest. A calculation of the bone cancer from the same source, uranium mill tailings piles, with just three factor changes--the NRC estimate of annual bone dose, the risk estimate of bone cancer, each from the same place as the lung estimates, and the replacement of the lung model factor of 100, above, with a suggested factor of 240 for reduction of permissible bone dose by bone-seeking alpha emitting radionuclides by Morgan (Ref. 35)--gives:

$$1.6 \times 10^{5} \frac{\text{person-rem}}{\text{year}} \times 240 \times 7 \times 10 \times 120{,}000 \text{ years} \times$$

$$7 \times 10^{-6} \frac{\text{bone cancers}}{\text{rem}} = 2 \times 10^{9} \text{ bone cancers.}$$

While these numbers may be arguably high they may be equally arguably low. The long term population estimates and their inherent inaccuracies should tend to make futile any arguments about factors of 10, 100, or even 1,000 applied to make these numbers higher or lower. The induction of a billion cancers from just one small portion of the nuclear fission program should serve notice on the responsible government agency that the radioactive waste problems are the most serious health problem caused by man. This message has been ignored, confused, and denied by the AEC-NRC-ERDA complex. We trust the EPA is less insensitive to public health.

It is frequently pointed out that any doses to the public from the nuclear power program represent only very small increases over background levels and that cancer deaths caused by these small doses are insignificant when compared to the natural causes of cancer, whatever they are (Ref. 36). We reject such callous attempts to justify what must be called murder by belittling the effects of deaths caused by radiation released by man's activities. In 1974 about 1,934,000 persons died in the United States (Ref. 37). If someone, in the course of his business, felt it necessary to shoot someone, did so, causing death, was apprehended, and brought to trial, we genuinely doubt that any jury would be moved to acquittal by the argument that the death in question was insignificant compared to the "background" death rate. Death as a result of man's activities remains death by man's activities. The murder of one billion people by cancer, most of whom are yet to be born, cannot be dismissed in a cavalier manner as being just a small addition to those who would have died from cancer anyway.

The real difference between murder with a gun, club, or poison, for example, and murder by cancer induction is not related to the act itself. The real difference lies in the separation in time between the insult and the death, on one hand, and on the obvious differences in detectability of the causes of death by violence and that from man-induced cancer and a natural or spontaneous cancer. The act of murder remains the same. To condone or even promote murder indistinguishable from natural deaths while condemning what we legally consider homicide is hypocrisy of the highest order.

What, then, do we suggest to this conference to aid the Environmental Protection Agency in its present commendable attempt to wrestle with this hydra-headed problem?

First, to representatives of public interest organizations and state and local governments we would caution that it would be foolhardy in the extreme, given the present condition of uncertainty and the record of past errors in the management of radioactive wastes, for any community or governmental body to accept proposals for waste sites--either a high-level radioactive waste depository, or a commercial or governmental low-level waste burial site, or uranium mining and milling, or phosphate mining. What emerges from the literature, from the operating record, and from EPA's preliminary discussions of the proposed rulemaking on criteria and numerical standards is simply this: we really don't yet know what we're doing. We would strongly urge rejection of radioactive waste disposal until there is "light at the end of the tunnel." There must be legally binding, irrevocable guarantees that no more radioactive waste from military or commercial nuclear programs will be produced to add to the already demonstrably unmanageable burden on our society. This burden results, we believe, from past errors in allowing the wholesale production of these materials in the absence of appropriate means of disposal. We also suggest that EPA rigorously support such a position in the public interest.

We summarize the present state of uncertainty about the appropriate public policy to adopt for the management of radioactive wastes in the discussion that follows.

The fundamental problem that we must deal with lies in the nature of the health costs associated with radioactive wastes. All decisions relating to criteria and standards, and most assuredly all economic decisions, must turn upon one factor alone: the certainty that we fully understand in advance the effects of radiation on man and upon all other biological organisms of the ecosystem that are related to man. We submit that, despite claims that radioactivity has been studied more thoroughly than any other pollutant, our understanding of the subtle effects of low-level radiation exposures is almost totally lacking at the present time. We reject the argument that such matters lie in the realm of "trans-science" and are beyond our investigative powers. The past record of underestimating radiation effects cannot be carried into this decision-making process; we cannot afford to be wrong.

It has been argued that "economic feasibility" be a basic criterion in determining waste management methods. If a cost-benefit analysis is to be undertaken, it must not be based upon the monetary costs of alternative waste disposal technologies as the limiting factor. The cost-benefit ratio must be computed on the basis of the full health costs to the future.

Thus, we face a set of dilemmas and contradictions that have had virtually no recognition or understanding in the past and that must be resolved.

1. The ethical dilemma. Criteria for radwaste standards must be based upon a clear understanding of who and what are to be protected. Radwaste management is not merely a matter of individual ethics, where decisions are based upon an individual's assessment of "good" essentially for himself. A policy that permits economic considerations by today's population, for

current profits today, to neglect health costs to the future cannot be called responsible societal ethics. Most human beings, despite certain evidence to the contrary throughout history, do have an ethical concern for the survival and well-being of their descendants. But, in this case, a societal ethic concerned only with the protection of mankind is not adequate. We must adopt an ecological ethic which would consider radiation impacts upon all life forms. We stress that species protection of the biosphere is our environmental responsibility and our own best guarantee of survival.

2. The temporal dilemma. Related to the ethical question, we must decide how many generations into the future we are obligated to protect. The health effects calculations reported above clarify beyond argument that we have a multi-million year problem. If our waste management policy, for either high-level or low-level radwastes, is designed to minimize exposure for only our own generation or a mere few hundred years, then the responsible agencies must make absolutely clear the magnitude of the delayed health costs to future populations and submit their admission of what can only be called deferred homicide to the public for their approval.

3. The spatial dilemma. In the past, relatively few low-level waste burial sites have been licensed to operate in the U.S., and until recently the search for a high-level waste depository has focused on finding the single best geologic site. ERDA has revised this policy in favor of a "spread the wealth" concept of regional high-level waste depositories. New commercial low-level burial sites are being sought. Mining of additional low-level uranium ores would add to the number of low-level waste sites. Dispersal or concentration would be no problem if there were no risk of leakage from any sites. Questions of distributive justice do, however, accompany waste siting, and we must determine how, with equity, to select a site or sites. Disposal practices of the past and present, in part designed to minimize costs in order to protect the economic viability of nuclear power, have led to the problems we now face. We suggest that a continuation of that philosophy toward waste disposal will lead irrevocably to the consequences we estimate.

4. The control dilemma. There is a paradox in the need for adequate monitoring of a waste disposal site and conversely the necessity for doing so without disturbing the integrity of its isolation. There is a further problem in the issue of ultimate responsi-

bility for control. The legal tangle of the West Valley site warns of the problem ahead of ensuring, within criteria and standards, the proper allocation of authority and responsibility.

5. The technical dilemma. The present EPA rulemaking is proceeding on the assumption that currently developed technologies are adequate, if carefully used, to produce the level of protection required for irretrievable radioactive waste disposal. We see no evidence that these burial methods, or others thus far proposed, can be depended upon for the time required.

6. The dilemma of civilization's stability. Nearly imponderable but nonetheless significant is the question of whether energy-intensive industrial societies can indeed reasonably expect further progress in "high technology." We have assumed such progress to solve the radwaste problem. Students of resource depletion population, food supply, and pollution have suggested, however, that our society may now be passing its developmental peak (Ref. 38). There may be no more nearly perfect technology developed in the future; the optimistic assumption that remaining problems can and will be solved may well be entirely unwarranted. After 2,000 or 3,000 years of science we have not solved the problems of human fallibility. This is a dilemma of enormous philosophical importance, to which no one has a definitive answer, least of all those who brought us the problems.

7. The credibility dilemma. The AEC failed to do its job properly and was abolished, leaving us its mistakes. So did the Joint Committee on Atomic Energy. The Price-Anderson Act failed, and has recently been declared unconstitutional by a Federal district court. The credibility of all those agencies and their personnel is justifiably low in the minds of American citizens. This complicates the task of EPA in its highly commendable endeavor to address the real nature of the dilemmas of radioactive waste management. Overcoming public reluctance to believe any governmental agency will require rejection by EPA of the traditional economic cost-benefit trade-offs that have characterized the approach of all who set and administered radiation standards in the past. The full costs to health and genetic integrity must finally be seriously addressed before any radwaste standard is acceptable.

We recommend to EPA and to this conference the following points:

1. The dose-commitment factor must be integrated to infinity.
2. In recognition of our proven inability to manage existing radioactive waste, no more radioactive waste should be produced for either military or commercial programs.
3. Criteria for radioactive waste management must be based upon the concept of zero release, and thus zero dose to the biosystem. No other standard will suffice.
4. "Economic feasibility" must be completely subordinated to prevention of health costs in the future as well as at present.
5. Other solutions to low-level and high-level waste isolation may prove to be preferable to those now available. Geologic storage from which wastes are safely retrievable for the near-term may be a better option than irretrievable disposal of long-lived wastes at the present time.

Finally, we reiterate our commendation to EPA for the thought and care its staff is now giving to this most troubling problem of the nuclear age.

1957 A-Bomb Test May Be Cancer Link

ATLANTA (UPI) — Two Army veterans who were exposed to an atomic bomb test on the Nevada desert 20 years ago may help a medical detective discover whether there is a link between exposure to low radiation levels and cancer.

The men, Paul Cooper, 43, of Salt Lake City, and Donald Coe, 44, of Tompkinsville, Ky., were on duty at Yucca Flats, Nev., on Aug. 31, 1957, when the Army detonated a 44-kiloton atomic bomb. They were among 1,100 men stationed less than two miles from the test site.

Meanwhile, the Nuclear Regulatory Commission was urged Monday in Washington to strengthen its surveillance of atomic power plants by beefing up its inspection force to put one inspector at every site.

WITH A CURRENT force of 867 persons,the NRC inspection office concentrates on a review of atomic power plant operating records to watch for possible safety violations. An inspector can be expected to visit one of the 58 licensed nuclear power plants once every two weeks.

Dr. Glyn Caldwell, chief deputy at the national Center for Disease Control's cancer branch, said Monday his attention was drawn to Cooper's condition, granulocitic leukemia, by Veterans Administration doctors who knew of the CDC's interest.

"The scientific question is: Are these cases of leukemia delayed responses to low level radiation?" Caldwell said.

"When we have two out of 1,100 persons developing leukemia, there's a possibilty that they went through a common experience," he said. The chances of coming down with leukemia are about 10 per 100,000 persons on a purely random basis, he said.

COOPER'S ARMY doctors said he could die at any time. Coe has "hairy cell" leukemia, a different but still fatal type, according to CDC cancer specialists.

"We need to find all the men who were exposed to the radiation and then we might be able to identify the low level of radiation as a cause of malignancies," said Caldwell.

Finding all the men won't be easy, Caldwell said.

From the Wichita Eagle,
April 19, 1977

Men exposed to '57 nuclear test

Army unit could be key to major leukemia study

Associated Press

ATLANTA — The lost roster of an airborne unit that was exposed to an atomic bomb test in Nevada in 1957 could be the key to an important study of leukemia, the national Center for Disease Control said yesterday.

Two former members of the 504th Airborne Infantry Regiment of the 82nd Airborne Division, Ft. Bragg, N.C., are known to have acute leukemia, a cancer that attacks the white blood cells, the disease center said.

There could be others, some of whom may already be dead, a spokesman said.

Dr. Glyn G. Caldwell, deputy chief of the disease center's cancer branch, wants to locate the other members of the unit — about 250 men.

Others were exposed to radiation during atomic tests at Yucca Flats. But Caldwell said the 504th would give scientists a specific group with which to work.

"What I am trying to do is to zero in on the 1957 test," Caldwell said. "I hope to find out if this group had an increased risk of leukemia, or cancer in general, compared with the national average."

The Army's official roster of the 504th apparently was lost in a fire at the St. Louis records center in 1973.

The two former members of the unit known to have leukemia were identified as Donald Coe, 44, of Tompkinsville, Ky., and Paul R. Cooper, 43, who is in a Veterans Administration hospital in Salt Lake City.

Cooper has filed a claim for service-connected assistance, claiming his unit was deliberately exposed to radiation.

Caldwell said his attention was called to the matter by the disease center's Epidemic Intelligence Service, which investigates epidemics.

Caldwell said he has received numerous calls from other people who were at tests as far back as 1945. He said Cooper claims as many as 1,100 people were in the immediate area at the time of the 1957 test.

"We know that people exposed to radiation at Hiroshima and Nagasaki had an increase in leukemia among survivors," he said. "The difference is that they were subject to tremendous doses. The average safe dose for radiation in this country is recognized as five rads, while the Japanese got greater than 100 rads per dose."

He said the soldiers in the 504th received about one and one-quarter rads per dose.

A rad is a unit of measurement of an absorbed dose of radiation.

Caldwell said studies showed the rate of leukemia in Japan before the atom bomb explosions was about what it is in this country — about 10 cases per 100,000. But it increased tremendously for about seven years after the war, and then dropped to the previous level, he said.

From the Louisville Courier-
Journal, April 21, 1977

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ENVIRONMENTAL IMPACT STATEMENT COMMERCIAL RADIOACTIVE WASTE MANAGEMENT*

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The Energy Research and Development Administration (ERDA) is preparing an environmental impact statement to evaluate the impact of waste from the light water reactor (LWR) fuel cycle. The statement is generic in nature. It does not identify specific sites where facilities for waste treatment and final isolation may be located. It analyzes typical facilities and typical environments. The statement is not prepared for any licensing purposes. Specific statements for specific sites will be required.

The purposes of the statement are to define available processes for managing post-fission waste from the commercial LWR fuel cycle, to define integrated systems using those processes, to assess the environmental impact of those processes and systems operating under various options of the LWR fuel cycle, and to aid in the decision-making process for waste management research and development programs.

The statement will inform the public of the state of knowledge and the impacts of using currently available technology for waste management. In addition, the statement will provide an opportunity for public comments on the waste treatment, interim storage, transportation, and final isolation options.

Public input during the preparation of the statement was solicited in several ways. First, the comments previously received on the withdrawn environmental impact statement Management of High-Level and Transuranium-Contaminated Radioactive Waste (WASH-1539) were reviewed. Comments were received as a result of a Federal Register notice announcing the preparation of this statement. In addition, comments made at a meeting held in Denver to discuss technology alternatives of waste management and a meeting held in Chicago to discuss socio-economic issues of waste management are being considered. The comments and discussions at these meetings provided insight into public opinion on real and perceived problems associated with radioactive waste management.

The statement is limited in scope to postfission waste from light water reactors. A comparative analysis of nuclear power and other power generating options is not included. The

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* This paper is based on work performed under Energy Research and Development Administration Contract E(45-1)-1830.

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statement addresses waste characteristics and volumes, facility descriptions and waste treatment alternatives, transportation, interim storage, and final isolation of the waste in deep geologic formations. The potential environmental impacts and dollar costs are evaluated for each step in the waste management process. The environmental impacts considered are those associated with radioactive materials, industrial pollutants, and social-economic changes. The decommissioning of typical facilities is also evaluated.

ERDA has selected Battelle, Pacific Northwest Laboratories (BPNL), for the overall management of the statement preparation. BPNL, in turn, has established some 33 Task Leaders throughout some 12 ERDA laboratories to lead the contributions in specialized technology areas. In addition, several contracts to private industry have been let.

The statement will analyze three LWR fuel cycle options: (1) once-through, (2) uranium-only recycle, and (3) uranium-plutonium recycle. The technical bases for the statement are the technologies presented as "available" within the Technical Alternatives Document, ERDA-76-43, with appropriate updating. The nuclear power industry growth is projected for this study at 500 GWe in the year 2000. The waste volumes considered include all those generated by reactors built through the year 2000 and operated through the year 2040. A reactor size of 1,200 MWe is used. Typical fuel processing plants of 2,000 metric tons per year, mixed-oxide fuel plants of 400 metric tons per year, and independent spent fuel storage facilities at 3,000 metric tons per year are considered and their environmental impacts analyzed. Deep geologic formations are analyzed for final isolation. For the draft statement, most of the analyses will center on salt as the geologic formation for waste isolation since this is the media for which quantitative performance data is available. Many studies and engineering efforts are in progress to advance the knowledge for waste isolation in argillaceous formations and crystalline rock. Geologic isolation of waste in these latter media is discussed within the current range of knowledge relating to them. Research and development programs and special studies are in progress to evaluate seabed disposal, and partitioning, which is important to further studies on transmutation and extraterrestrial waste disposal or isolation technologies. At the present time, these technologies are not as well developed or understood as geologic isolation in salt, argillaceous formations, or crystalline rock.

The environmental analyses follow the usual impact statement format, providing analyses of construction and the operational features of waste management facilities such as land use, water use, thermal and chemical discharges, ecological impacts, social-economic impacts, and radiological impacts. The radiological impacts include calculations of the population dose, potential health effects, and the environmental dose commitments from the operation of waste management facilities.

In addition to analyzing environmental impacts from normal operations, conditions resulting from accidents are examined. For treatment facilities, minor accidents such as might occur on a frequent basis with no external releases are analyzed. Moderately sized accidents which are the largest normally anticipated to occur and which might release small amounts of radioactive material to the environment are analyzed. The most severe accidents considered are those which fully tax the safety systems of the facilities. For the final geologic isolation media, the accident analyses do include major earthquakes, water intrusion into the repository, and human intrusion by surface drilling or mining in a repository area.

The cost-benefit analyses are prepared using generic operational parameters, typical facilities, and reference environments. Waste management integrated system analyses are being included for selected waste management treatments to provide for handling all waste assigned to ERDA for disposal from the time of generation in LWR's until final isolation in a geologic formation. Waste volumes, environmental impacts, and costs will be examined by use of the integrated system to determine the total environmental impact for each of the three fuel cycle options. This analysis will provide a complete examination of the waste management system, its cost, and impact based on current available technology.

In summary, the statement is generic in nature, evaluating the environmental impact of nuclear waste management using today's available technology for waste treatment and final isolation. A multidisciplinary approach is being taken, combining expertise in waste treatment technologies, environmental and socio-economic areas, and cost-benefit analyses to assure an integrated waste management system evaluation representing today's capability to handle radioactive waste.

SUMMARY OF ALTERNATIVES FOR LONG-TERM MANAGEMENT OF DEFENSE HIGH-LEVEL RADIOACTIVE WASTE, SAVANNAH RIVER PLANT, AIKEN, SOUTH CAROLINA*

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FOREWORD

This document was prepared to provide other government agencies and the public information on possible alternatives which will be considered for the long-term management of Savannah River Plant high-level nuclear waste. It describes a number of alternative plans for long-term management or disposal of the high-level nuclear wastes now stored in tanks at the Savannah River Plant near Aiken, South Carolina. The description includes implementation technology, risks to the public, and preliminary budgetary cost estimates.

It does not, however, take into account social and public policy issues. Instead, the document presents factual information on the aspects of alternatives that are possible to quantify (costs and risks), so as to serve as a basis for discussion and judgment in future decision making. No selection of an alternative for implementation is made in this document. Comments will be taken into account in selecting a proposed Agency action and will be included in the environmental impact statement prepared to assess in detail the potential environmental impact of that proposed action. The selected program will be conducted in accordance with all environmental, health, and safety requirements.

This report was prepared for the Energy Research and Development Administration (ERDA) by the technical staff of the Savannah River Laboratory.

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INTRODUCTION

Since 1953, the Savannah River Plant (SRP) near Aiken, South Carolina, has been producing special nuclear materials, primarily plutonium and tritium, for defense purposes. The SRP facilities were constructed and initially operated for the Atomic Energy Commission. Operation since 1975 has continued under the direction of the Energy Research and Development Administration.

The SRP operations produce high-level radioactive waste in the chemical processing of fuel and target elements after irradiation in the SRP nuclear reactors. This waste is stored as an alkaline liquid with a precipitated sludge until the decay heating has abated appreciably. Then the supernatant liquid is converted to salt cake to reduce volume and mobility. The storage facilities are large underground tanks that are engineered to provide reliable isolation of waste from the environment.

While high-level waste has been and is continuing to be stored safely in present facilities at SRP, it is important to establish long-range goals and policies that will govern ultimate management or disposal of the waste with assurance that the interest of future generations is considered. Many alternative approaches to long-term waste management have been identified, and a considerable amount of effort has been devoted to study and research into selected methods.

The purpose of this site-specific document is to describe the different alternatives along with their probable relative costs, risks, and uncertainties. A secondary purpose is to raise the issue of methodology for decision making in nuclear waste management. The document does not attempt to arrive at any recommendations.

Before any long-range waste management plan is implemented, an environmental statement will be prepared to conform with the requirements of the National Environmental Policy Act. This environmental statement will provide the formal mechanism for review and comment on the plan. The present document was written to provide for an early involvement of all interested parties so that all views can be factored into the selection process.

The document does contain a preliminary listing of the SRP alternatives including a simple cost-risk analysis. In this analysis, risk is assumed to be the product of consequence times probability over the full range of possible hazards, and the consequences are assigned monetary values, so that risk can be treated as an equivalent cost. The waste management alternatives can then be ranked in order of total effective costs. Total effective cost is the sum of the estimated management costs and the estimated risk costs. At this time, many of the component estimates are preliminary and subject to revision. Also, a number of important considerations such as compatibility between commercial and defense waste management, social issues and public acceptance are not included in the analysis. For those readers who wish to make their own analyses, information on the different factors is available in the text.

SUMMARY

Implementation costs and risk costs are calculated in the text for 23 alternative plans for long-range management and isolation of the SRP high-level radioactive waste. For purposes of basic programmatic decision making, these 23 plans can be grouped into four main classes (Figure 1).

1. Convert the waste to a highly leach-resistant form, such as canned glass cylinders, and ship it offsite to a Federal repository.*
2. Convert the waste to a highly leach-resistant form, and store the waste in an engineered surface facility at SRP.*
3. Reconstitute the waste to a slurry, and dispose of it in a bedrock cavern under the SRP site.
4. Continue storage in tanks with the waste as salt cake and sludge.

Most of the alternative plans are in turn divided into four main functional modules:

1. Removal from tanks.
2. Processing.
3. Transportation.
4. Storage.

These functional modules can be analyzed almost independently of each other. Thus, if the reader desires, it is relatively easy to extend the analysis to other cases by altering individual modules and by combining the limited number of modules into a large number of plans.

Costs for accomplishing each alternative were established from preliminary engineering studies that were based on the best available process specifications. The estimates are not budget quality, but they are sufficiently accurate for gross cost ranking of the alternatives. All of the alternatives

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* Alternatives are also considered in which the waste is converted to a dry calcine or to a fused salt, the latter with no separation of the high-activity fraction from the bulk of the waste.

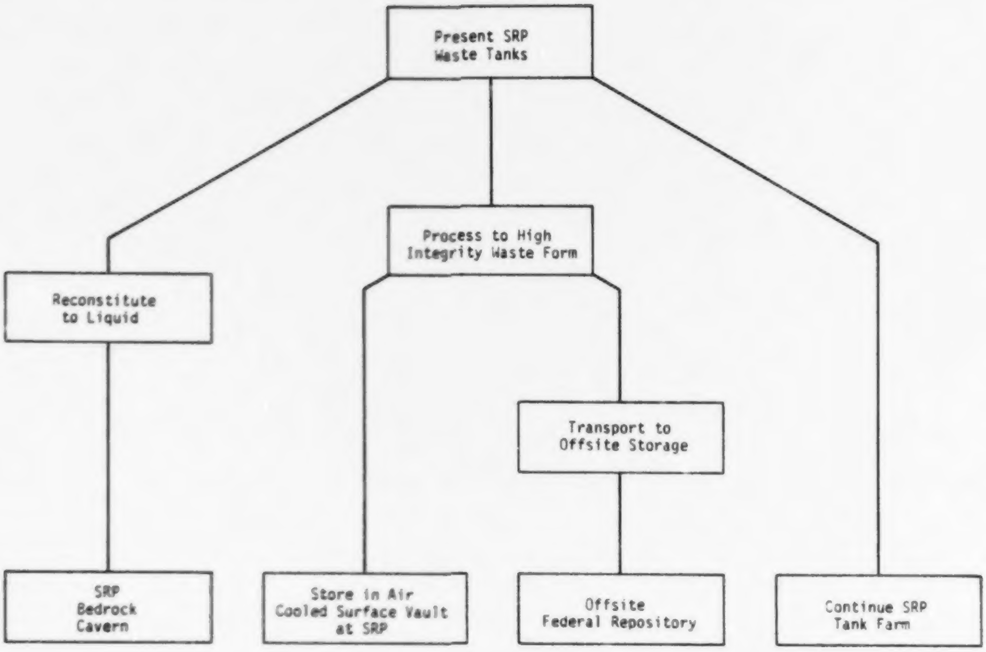
Present SRP
Waste Tanks
Reconstitute
to Liquid
Process to High
Integrity Waste Form
Transport to
Offsite Storage
SRP
Bedrock
Cavern
Store in Air
Cooled Surface Vault
at SRP
Offsite
Federal Repository
Continue SRP
Tank Farm

Figure 1. Major alternative plans.

are expensive to implement, but there are also large differences between them. Costs range from several hundred million to several billion dollars. The large cost differences between alternatives directly reflect the large differences in effort required between, at the low end, slurrying waste directly into an onsite cavern and, at the high end, constructing and operating extensive new processing and storage facilities.

Risks for each module are established by calculating the consequences and probabilities for each of the following types of events:

1. Routine radioactive releases.
2. Major process incidents.
3. Natural disasters such as tornadoes and earthquakes.
4. Sabotage.
5. Airplane crash.
6. Abandonment.

The diagram shown in Figure 2 gives the method used in making the risk estimates and shows the types of data available in the main text. It is intended that the technical basis and results of each step in the risk analysis be available in the text for scrutiny and comment.

Offsite risks are almost exclusively radiological. They are initially determined in man-rem* exposure probabilities to the surrounding population over a 300-year period and in contamination probabilities to the surrounding land. (Contamination risks to land proved to be negligible when compared with population exposure risks.) The risks are then translated into dollars by assigning a cost of $1,000/man-rem as recommended by the Office of Management and Budget and the Nuclear Regulatory Commission (NRC) for cost-benefit analyses of reactor safety systems and radwaste systems.

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* Man-rem is the total radiation dose commitment to a given population group; the sum of the individual doses received by a particular population group.

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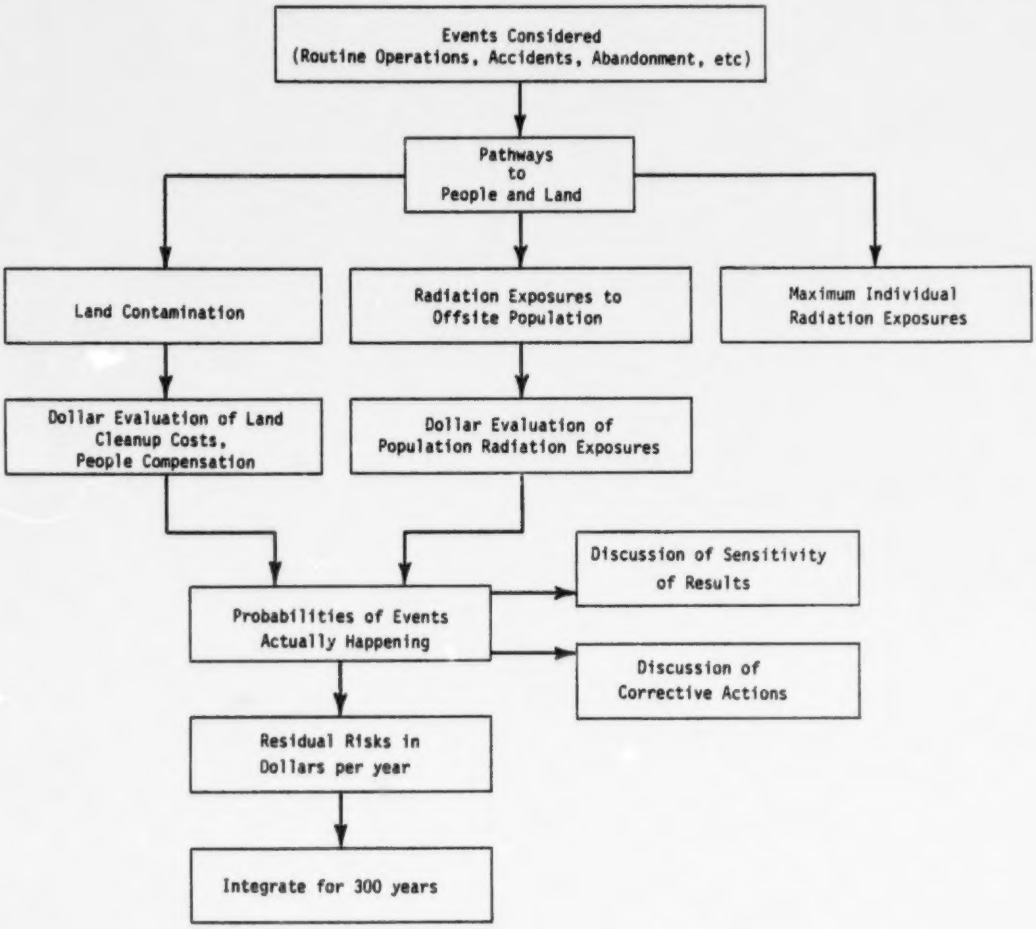
Events Considered
(Routine Operations, Accidents, Abandonment, etc)
Pathways to People and Land
Land Contamination
Radiation Exposures to Offsite Population
Maximum Individual Radiation Exposures
Dollar Evaluation of Land Cleanup Costs, People Compensation
Dollar Evaluation of Population Radiation Exposures
Discussion of Sensitivity of Results
Probabilities of Events Actually Happening
Discussion of Corrective Actions
Residual Risks in Dollars per year
Integrate for 300 years

Figure 2. Method for developing risk estimates.

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On this basis, the dollar value of risks of all the alternatives is small compared with the implementation cost of any alternative or with the cost differences among alternatives.**

Examination of radiological consequences directly in terms of possible man-rem exposures without application of probabilities or dollar values also indicates low risk. Offsite radiation doses that could result from credible events that have so far been identified are generally below the ERDA standard of 170 mrem/year for individual members of the public living near nuclear facilities. A few maximum individual doses could be above the 5-rem/year occupational limit for workers in the nuclear industry, but there is no credible potential for substantially higher offsite doses. Although the calculated consequences are of concern, they are not major disasters nor do they have long-term effects on society. Producing an effect that could appropriately be called a disaster would require events such as sabotage with incredible amounts of conventional explosive or with nuclear weapons, impact of large meteorites, or other events so improbable as to be almost irrelevant in the consideration of the alternative plans. In particular, the consequences of sabotage are probably so small that, as this fact becomes accepted, the wastes are not likely to be an attractive target for terrorists.

Some of the important physical reasons why the hazards associated with the waste are limited include:

** The validity of interpreting man-rem exposure to a population as actual risk is in doubt and may be a gross overestimate of risk when exposure to the involved individuals is very low. The following excerpts on this subject are Report No. 43 of the National Council on Radiation Protection (NCRP), January 15, 1975:

> The indications of a significant dose rate influence on radiation effects would make completely inappropriate the summing of doses at all levels of dose and dose rate in the form of total person-rem for purposes of calculating risks to the population on the basis of extrapolation of risk estimates derived from data at high doses and dose rates.
>
> The NCRP wishes to caution governmental policy-making agencies of the unreasonableness of interpreting or assuming 'upper limit' estimates of carcinogenic risks at low radiation levels as actual risks, and of basing unduly restrictive policies on such an interpretation or assumption.

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1. Very large amounts of energy are required to create waste particles small enough to be widely distributed through the airborne pathway. This is true on a per curie basis for the salt cake and sludge currently stored in tanks as well as for the high-integrity forms like glass.
2. There are no inherent internal sources of high energy in the waste management systems. Energy required to release radioactive particles would have to be introduced externally and in some abnormal manner.
3. There are no radioactive noble gases or significant amounts of easily volatilized radioactive elements in the waste that could contribute to potential doses from the airborne pathway.
4. High-integrity waste forms and engineered surface or geologic storage facilities can impose major barriers against waste migration.
5. Liquid releases from SRP would be absorbed in the soil or diluted many orders of magnitude by the onsite creeks and swamps and by the Savannah River before reaching drinking water users. Even if diversion systems fail and no corrective actions are taken, no large individual doses can occur. None of the alternatives propose handling liquid wastes at any site other than the SRP site.
6. The SRP waste facilities are within a large exclusion area surrounded by land of low population density.

Table 1 summarizes the results of the study for four waste management plans representative of the four main classes of SRP alternatives. Column 1 gives the estimated implementation cost in undiscounted 1976 dollars.* Column 2 gives the population dose risk in man-rem; this risk is evaluated as a sum of consequence times probability for the range of incidents discussed earlier. Column 3 gives the total effective cost, which is the sum of implementation costs and the population dose risk (valued at $1,000/man-rem). Column 4 gives the cost in implementation dollars per man-rem reduction in probable population dose risk for choosing methods other than the lowest cost implementation method (i.e., bedrock storage of a waste slurry in a cavern below SRP).

In the first alternative, waste is slurried out of the tanks after the evaporated salts are redissolved in recirculated water. The waste is then separated into a high-activity fraction occupying about 10 percent of the solids volume and decontaminated salt containing less than 6 nanocuries per gram of radioactivity. A glass is formed from the high-level

---

* Note that these costs can be expected to increase substantially by escalation during the actual implementation period.

TABLE 1 SUMMARY OF RESULTS OF STUDY OF WASTE MANAGEMENT ALTERNATIVES

Alternative	Budgetary Cost (billion 1976 dollars) (a)	Population Dose Risk (thousand man-rem) (b)	Total Effective Cost (billion 1976 dollars) (c)	Incremental Cost/Risk ($/man-rem) (d)
Glass shipped offsite to Federal repository. See Plan 1, Table 3.	2.7	0.90	2.7	41,000
Air-cooled vault with glass at SRP. See Plan 5, Table 3.	2.9	0.22	2.9	44,000
Liquid waste slurry stored in SRP bedrock cavern. See Plan 22, Table 3.	0.18	62	0.24	Base
Continued tank farm operation with salt and sludge. See Plan 23, Table 3.	0.24 (e)	1.4	0.24	1,000

(a) Undiscounted.

(b) Integrated for 300 years. Assumes population grows by a factor of 5 by 2140, then remains constant. No corrective action.

(c) Radiation doses were evaluated at $1,000/man-rem.

(d) Costs per man-rem reduction in risk, using the least expensive alternative (Liquid stored in SRP bedrock cavern) as a base. For example, in Plan 1:

$$\frac{(2.7 - 0.18)\,(\text{billion dollars})}{(62 - 0.9)\,(\text{thousand man-rem})} = 41{,}000\ \frac{\text{dollars}}{\text{man-rem}}$$

(e) Includes undiscounted costs for one generation of new tanks, starting about year 2040. This investment is more than that required to create a trust fund to rebuild tanks into the indefinite future. Such a trust fund would require new legislation for its creation. If costs are simply summed over the full storage time, they amount to about $250 million every 50 to 100 years for tank surveillance and replacement.

fraction at a concentration of about 35 percent waste in the borosilicate glass formers. The glass is then put in single cans and transported to an offsite geologic storage site. The salt is canned and stored in a surface vault at SRP. Transportation risks for the high-integrity glass were found to be very low. The disposal risks from several candidate geologic respository formations are now being studied by other groups as part of ERDA's terminal storage program for wastes from commercial reactors. As the studies are completed, their results will be factored into the analysis given in this document. For this analysis, it was assumed an offsite Federal repository would be located in bedded salt or other formation with no likely pathway to a water supply. Therefore, the primary risks are caused by removal from tanks, processing, and transportation. All of the required processes have been demonstrated on a laboratory or pilot plant scale.

The second alternative is almost identical to Alternative 1 except the high-level fraction is assumed to be double-canned in steel cans--the external can is about 2 ft in diameter and 10 ft long--and is placed in a large engineered surface storage facility at the SRP site. In this particular version, the decontamination salt is also canned and stored in a surface vault. Costs are about 10 percent higher than for Alternative 1 because of the very large costs calculated for a surface storage facility which would give equivalent protection to geologic storage. Such costs more than offset the additional transportation step required in Alternative 1. Risk costs are estimated at $220,000 for this alternative versus about $900,000 for Alternative 1; they result mainly from removal from tanks and processing.

The third alternative has the lowest processing costs of any of the alternatives. It involves slurrying the wastes from the existing tanks into a bedrock cavern dug in an impermeable Triassic mudstone under the SRP site. This alternative was extensively investigated, and it appears to be feasible. However, in 1971 all further work on this alternative was deferred until the alternatives involving waste solidification could be investigated. The main radiation risk for Alternative 3 is the possibility of waste entering the Tuscaloosa aquifer above the Triassic mudstone as the result of an earthquake or sabotage before the shaft connecting the cavern to the surface has been sealed. The probability of occurrence of either of these events is low, and the total probability of contamination is reduced further by engineered features of the shaft and the immediate presence of the manpower and equipment needed to repair or seal the shaft. There is also a risk, estimated at 8×10^3 man-rem ($\$8 \times 10^6$), arising from the possibility of small cracks forming to connect the cavern to the aquifer. The probability of such cracks is not known with a good degree of certainty, but the assigned risk is believed to represent an upper limit.

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The fourth alternative is continued storage in tanks with tank replacement every 50 to 100 years as required by tank condition. Basically, this alternative is an indefinite extension of present waste management practices, which will in fact prevail until another alternative is selected and funded. It is calculated to have the lowest overall cost if tank replacement cost is calculated on a discounted basis. It has the highest cost if tank costs for thousands of years are summed on an undiscounted basis. The risk for Alternative 4 is dominated in about equal parts by a hypothetical tank explosion and by an assumed abandonment of the tanks.

All the risks shown in Table 1 assume no measures are taken to reduce radiation doses to the population immediately after the occurrence. As discussed in the full text in Section X (see Appendix), there are fairly straightforward corrective action steps that would probably be taken, and these steps have the capability of reducing most risks tenfold. The risks from Alternative 3 could be reduced about one hundredfold by such steps.

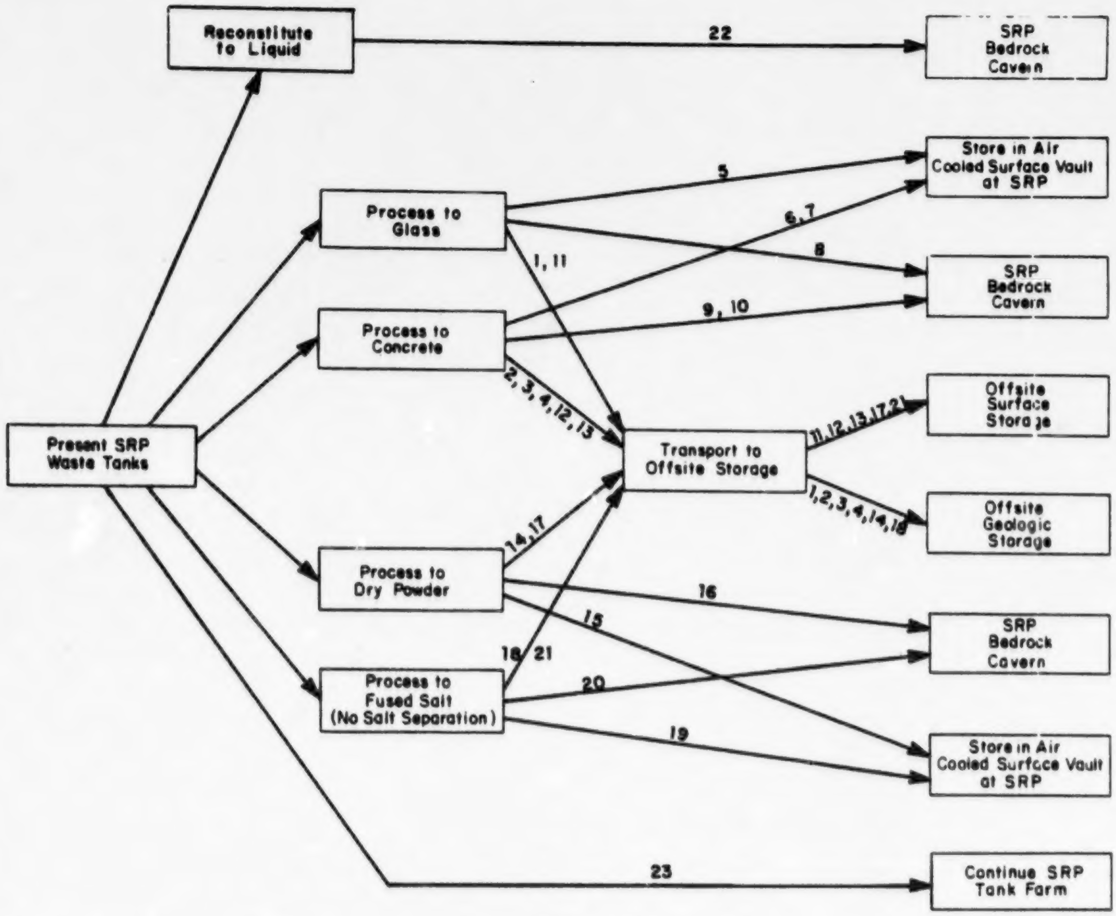
All the alternative plans provide for isolation of the decontaminated salt, either through storage in tanks or disposal by methods similar to those used for the high-level fraction. The consequences of introducing the decontaminated biosphere through hypothetical abandonment of tanks were also analyzed. The results show that no unusual hazard is associated with such dispersal.

The four major classes of SRP alternatives discussed above are expanded into 23 alternative plans by considering:

1. Variations in the final form of the high-level fraction to include concrete and dry powder.
2. A final waste form of fused salt with no separation of the high-level fraction from the large bulk of salt.
3. Variations in the final storage or disposal mode to include an offsite surface vault and disposal of canned, solidified waste in an SRP bedrock cavern.
4. Variations in the final storage or disposal mode for the decontaminated salt.

Figure 3 shows in schematic form how these 23 alternatives arise, and Table 2 gives the definition of important characteristics of each.

Considerable amounts of research, development, and small-scale demonstration have been done on the important aspects of all the alternatives, and all are judged attainable with additional development costs that are estimated to be small fractions of the total cost of any alternative. All the geologic disposal options would require construction and oservation of large-


Reconstitute to Liquid
22
SRP Bedrock Cavern
Store in Air Cooled Surface Vault at SRP
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6, 7
8
1, 11
SRP Bedrock Cavern
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2, 3, 4, 12, 13
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11, 12, 13, 17, 21
Present SRP Waste Tanks
Transport to Offsite Storage
1, 2, 3, 4, 14, 18
Offsite Geologic Storage
14, 17
Process to Dry Powder
16
15
SRP Bedrock Cavern
18, 21
Process to Fused Salt (No Salt Separation)
20
19
Store in Air Cooled Surface Vault at SRP
23
Continue SRP Tank Farm

(Numbers shown on the arrows are alternative plan numbers used in Tables 2 and 3.)

The following salt disposal options are discussed for alternative plans that produce separated, decontaminated salt:

1. Storage in Surface Vault at SRP (Plans 1,2,5,6,11,12, 14,15,17).
2. Storage in Offsite Surface Vault (Plan 13).
3. Storage in Decontaminated SRP Tanks (Plans 3,7).
4. Disposal as liquid in SRP Bedrock (Plan 10).
5. Stored as Canned Solid in SRP Bedrock (Plans 8,9,16).
6. Offsite Geologic Disposal (Plan 4).

Note: Plans 18-23 do not produce separated, decontaminated salt.

Figure 3. Major alternative plans for SRP high-level waste management.

TABLE 2 DEFINITION OF 23 ALTERNATIVE PLANS

Plan No.	High-Activity Fraction											Decontaminated Salt Fraction							
	Waste Form						Location					Waste Form			Location				
							On Site			Off Site					On Site			Off Site	
	Glass	Concrete	Dry Powder	Fused Salt	Salt Sludge	Liquid	Geol.	Vault	Tanks	Geol.	Vault	Dry Bulk	Canned	Liquid	Geol.	Vault	Tanks	Geol.	Vault
1	x									x			x			x			
2		x								x			x			x			
3		x								x		x					x		
4		x								x			x					x	
5	x							x					x			x			
6		x						x					x			x			
7		x						x				x					x		
8	x						x						x		x				
9		x					x						x		x				
10		x					x							x	x				
11	x										x		x			x			
12		x									x		x			x			
13		x									x		x						x
14			x							x			x			x			
15			x					x					x			x			
16			x				x						x		x				
17			x								x		x			x			
18				x						x									
19				x				x											
20				x			x												
21				x							x								
22						x	x												
23					x				x										

Note:

Plans 18 through 23 do not produce separated, decontaminated salt.

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scale exploratory shafts for a time period long enough to give a high level of confidence of their continued integrity after sealing.

The 23 alternatives are different in method of implementation, in monetary cost, in risk, and in administrative responsibility left to future generations. However, they do all come to the same logical cost and risk endpoint in that:

1. Each alternative isolates the waste from man's environment with a low degree of risk far enough into the future that the waste poses a negligible threat.
2. The cost for carrying each alternative into such future time is given, assuming a monetary discounting philosophy. The cost consequences for not discounting are presented.
3. The risks integrated into such future time are given, without discounting, and including the risk of abandonment.

The fact that the risk from each alternative is in a reasonable range for consideration regarding its acceptability is demonstrated by the finding that:

1. The population dose risk evaluated in dollars is small compared to the budgetary cost of implementation.
2. Individual doses to members of the general public, even if some of the more unlikely events did occur, are small compared to currently accepted standards and compared to variations in doses from naturally occurring radioactivity.

Table 3 gives a summary of budgetary costs and population dose risks for each of the 23 alternative plans. A sample cost-risk analysis is also given, using the methods described previously for Table 1.

Within the framework of the preliminary analysis, the following may be stated:

1. A number of alternatives exist for safely managing the SRP high-level radioactive wastes at costs (in constant dollars) between 10 and 30 percent of the costs of the operations originally generating the wastes.*

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* Because of the low fuel burnup and other special requirements of radioisotope generation at SRP, these costs are much higher on a percentage basis than those of power reactor waste management. Comparable management of power reactor waste is estimated to be only about 1 percent of the power generation costs.

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TABLE 3 SUMMARY OF COSTS AND RISKS FOR 23 ALTERNATIVE PLANS

Plan Number	Plan Description	Budgetary Cost (billion 1976 dollars) (a)	Population Dose Risk (thousand man-rem) (b)	Total Effective Cost (billion 1976 dollars) (c)	Incremental Cost/Risk ($/man-rem) (d)
1	Glass disposed of in offsite geologic storage and canned decontaminated salt cake stored in outside surface storage facility	2.7	0.90	2.7	41,000
2	Concrete disposed of in offsite geologic storage and canned decontaminated salt cake stored in onsite surface storage facility	2.4	0.90	2.4	36,000
3	Concrete disposed of in offsite geologic storage and decontaminated salt cake stored in onsite underground waste tanks	1.2	0.90	1.2	17,000
4	Concrete and canned decontaminated salt cake disposed of in offsite geologic storage	1.9	0.90	1.9	28,000
5	Glass and canned decontaminated salt cake stored in onsite surface storage facility	2.9	0.22	2.9	44,000
6	Concrete and canned decontaminated salt cake stored in onsite surface storage facility	2.8	0.22	2.8	42,000
7	Concrete stored in onsite surface storage facility and decontaminated salt cake returned to onsite waste tanks	1.7	0.22	1.7	25,000
8	Glass and canned decontaminated salt cake disposed of in SRP bedrock	2.0	0.34	2.0	30,000
9	Concrete and canned decontaminated salt cake disposed of in SRP bedrock	1.8	0.34	1.8	26,000
10	Concrete and decontaminated salt solution disposed of in SRP bedrock	1.3	0.34	1.3	18,000
11	Glass stored in offsite surface storage facility and decontaminated canned salt cake stored in onsite surface storage facility	3.0	0.53	3.0	46,000
12	Concrete stored in offsite surface storage facility and canned decontaminated salt cake stored in onsite surface storage facility	3.0	0.73	3.0	46,000
13	Concrete and decontaminated salt cake stored in offsite surface storage facility	3.4	0.73	3.4	53,000

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TABLE 3 (CONT.)

Plan Number	Plan Description	Budgetary Cost (billion 1976 dollars)[(a)]	Population Dose Risk (thousand man-rem)[(b)]	Total Effective Cost (billion 1976 dollars)[(c)]	Incremental Cost/Risk ($/man-rem)[(d)]
14	Dry powder disposed of in offsite geologic storage and canned decontaminated salt cake stored in onsite surface storage facility	2.3	0.93	2.3	35,000
15	Dry powder and canned decontaminated salt cake stored in onsite surface storage facility	2.5	0.38	2.5	38,000
16	Dry powder and canned decontaminated salt cake disposed of in SRP bedrock	1.8	8.6	1.8	30,000
17	Dry powder stored in offsite surface storage facility and canned decontaminated salt cake stored in onsite storage facility	2.6	0.89	2.6	40,000
18	Fused salt disposed of in offsite geologic storage--no separation of radioactivity	1.1	1.0	1.1	15,000
19	Fused salt stored in onsite surface storage facility--no separation of radioactivity	3.0	0.22	3.0	46,000
20	Fused salt disposed of in bedrock--no separation of radioactivity	0.90	8.6	0.91	14,000
21	Fused salt stored in offsite surface storage facility--no separation of radioactivity	3.5	1.0	3.5	54,000
22	Unprocessed waste slurry disposed of in SRP bedrock	0.18	62	0.24	Base
23	Storage of waste as sludge and damp salt cake in onsite waste tanks (present SRP waste management technique	0.24[(e)]	1.4	0.24	1,000

(a) Undiscounted.

(b) Integrated for 300 years. Assumes population grows by a factor of 5 by 2140, then remains constant. No corrective action.

(c) Radiation doses were evaluated at $1,000/man-rem.

(d) Cost per man-rem reduction in risk, using the least expensive alternative plan as a base (Plan 22, Unprocessed Waste Slurry Stored in Bedrock).

(e) Includes undiscounted costs for one generation of new tanks, starting about year 2040. This investment is more than that required to create a trust fund to rebuild tanks into the indefinite future. Such a trust fund would require new legislation for its creation.

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2. Continued storage in tanks has the lowest combination of costs and risks provided that discounted rather than total costs are used for tank replacement at 50-to-100-year intervals over the next 1,000 years or more. However, undiscounted costs are very high and the time span requiring positive action is very long. Thus, it may be desired to remove the wastes to a completely inaccessible location.
3. Bedrock disposal of wastes under the Savannah River Plant site has the second lowest combination of cost and risk, and the lowest budgetary costs.
4. Geological disposal of a high-integrity waste form such as glass canisters in a Federal repository is a very low-risk option that offers close compatibility to a method being developed for permanent disposition of high-activity wastes generated in processing of commercial power reactor fuels.

The framework of this analysis will eventually have to be expanded to include costlike penalties that might be assigned to alternatives to account for judgments and convictions of those who must eventually participate in the ultimate decision.

Another area where costlike evaluations or social value judgments could be applied is with regard to trade-offs between reponsibilities and benefits left to future generations. The largest difference in such responsibilities among the various alternatives is between continued tank farm operation and offsite geologic disposal; some social implications of these differences are discussed below. Assuming the identified, quantified risks given in the analysis are acceptable for either option, then items important for further consideration for decision makers include monetary trade-offs, future technological options, and manpower and land requirements.

For example, in considering monetary trade-offs, future generations would be left with the cost of building new tanks every 50 to 100 years and with their surveillance and maintenance, compared with negligible surveillance cost for a sealed geologic repository. The cost listed in Table 3 includes a trust fund to supply these requirements and the tank farm option is still less expensive by as much as $2.5 billion. The compounded future wealth generated by this $2.5 billion difference if it entered the private/public investment mainstream in a productive way could be a very large net positive benefit for future generations.

Regarding future technological options, continued tank farm operation versus geologic disposal would leave open alternative uses or disposal methods that might become available from technological advances. Furthermore, after a period of about 300 years the annual risk from tank storage is reduced about

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one thousandfold from the 1980 risk. A decision about the risks and responsibilities left to generations beyond the 300-year point might then be made using the summation of the judgment and technology of those to come during the intervening 300 years instead of 1980 judgment and technology.

In considering manpower requirements, continued tank farm operation would involve a commitment by future generations to supply a few trained people for maintenance, surveillance, and replacement. On the other hand, a sealed geologic repository could probably be monitored by one part-time, less well-trained person.

It is emphasized that neither the cost-risk analyses given in Table 3 nor the above examples of social value considerations are meant to preselect any alternative plan as best. Instead they are offered to stimulate consideration and comments by the public and from government and private organizations. These factors could significantly influence the ranking of alternatives and they will be considered in the future Environmental Impact Statement on long-term management of the defense high-level waste at the Savannah River Plant.

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POLICY AND TECHNICAL CONSIDERATIONS FOR HIGH-LEVEL RADIOACTIVE WASTE: SUMMARY AND CONCLUSIONS OF WORKING GROUP 1

INTRODUCTION

The goal of Working Group 1 was to suggest and, if possible, agree upon technical and policy bases for environmental protection criteria as they might relate to high-level waste. The working group consisted of about twenty individuals including representatives from the nuclear industry, utilities, environmental groups, and Federal and state governments.

The issues selected for discussion were derived both from the Issues and Objectives Statements for Topic 1 and from questions enunciated at the start of the working group session by the participants. These issues were occasionally restated for clarity, and the questions ultimately addressed are itemized below.

Relatively few agreements were reached during the deliberations, which touched upon a wide range of topics. Instead, a number of differing viewpoints were expressed on each issue. The following paragraphs summarize the working group's proceedings by identifying each topic discussed, specifying what consensus was reached (if any), and summarizing the relevant viewpoints expressed during the discussions.

DEFINITIONS

What are appropriate definitions of the following terms in establishing criteria and standards?

1. Radioactive waste
2. High-level waste
3. Disposal.

No consensus was reached on a definition for any of the terms. The discussion in each case started with review of the definition contained in the Issues and Objectives Statement. Various complications subsequently arose which could not be resolved, and they are reviewed below. The discussion concluded with an agreement that consideration of the other topics would not depend upon reaching a consensus on definitions.

RADIOACTIVE WASTE

There was no agreement on how to determine that a waste had no future use which might affect management of that waste.

On one hand, there was concern that calling a material "waste" might lead to its irrevocable disposal, thus denying its

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value. On the other hand, some felt that a material might not be designated as "waste" to avoid the environmental control that designation might entail. It was noted that few (if any) methods of disposal are irrevocable if cost is no object. An objection was also made to the semantic implications of the terms high-level and low-level, in that they might misleadingly imply relative importance.

HIGH-LEVEL WASTE

It was noted that Appendix F to 10 CFR 50 defined high-level waste as the first cycle extraction made from fuel reprocessing, or the equivalent. However, concern was raised as to when, or whether, spent fuel elements should be designated as waste. It was contended that it was not appropriate for the criteria to make any distinction between high-level or other categories of radioactive waste.

DISPOSAL

As noted in the discussion of waste, it was felt that waste disposed by almost any method could be recovered if enough resources were invested. Thus, the question became one of the ease of potential recovery. After some discussion of engineering strategies, the working group agreed that the criteria should apply to waste management in general (including transportation, etc.) rather than disposal. Thus, the issue of defining disposal became irrelevant.

UNPLANNED AND ACCIDENTAL EVENTS

If the Environmental Protection Agency (EPA) addresses unplanned events in its environmental protection criteria, what would be an appropriate and effective approach? What aspects of the disposal process and of the unplanned events should be addressed? Should the criteria and standards consider the worst possible accident hazards?

Working Group 1 reached a consensus that all unplanned and accidental events, regardless of their probability of occurrence, should be considered by the EPA in setting criteria. No consensus was reached on how EPA should address these considerations in criteria.

It was contended that the forthcoming generic programmatic environmental statement on the management of commercially-generated radioactive waste would probably not include analyses of the worst conceivable accident and failure possibilities of the high-level nuclear waste storage and disposal facilities under prime consideration (viz., deep geological storage and disposal [deep burial] and retrievable surface storage facilities). It was further contended that this was not wise and that in order to ensure the formulation of sound environmental protection criteria and standards, the authority for making the criteria and standards should require that a complete hazard analysis be made prior to attempting to form the specific criteria (i.e., an analysis of all conceivable waste containment failure probabilities which cannot be ruled out as impossible should be made, including the calculation of the potential contamination and harmful consequences, with allowance for the scientific uncertainties). It was countered that the analysis of the worst case failure possibilities is being made for the Energy Research and Development Administration (ERDA) program for waste isolation, but this was questioned.

During this discussion, the Workshop struggled with the question what specific criteria should be adopted to apply to "unplanned or accidental events" at waste facilities. One criterion was suggested as follows: The potential strontium-90 and cesium-137 contamination of surface ground soil and surface water should not exceed x curies per m^2 and y curies per m^3, respectively, for the worst possible failure possibility. Later, the numerical values of x and y would be established, making the criteria "standards." It was then contended that this criterion should be extended to include consideration of likelihood.

Some suggested that numerical probability values should be developed for the various accident and failure possibilities and included in the criteria such that a waste facility would be acceptable if the probability was below established levels. It was countered that probability values cannot be scientifically demonstrated--that they would depend on subjective component probability values (guesses), and that all that could be done is to make a judgment of likelihood on the basis of objective information.

It was noted that a full risk assessment for waste repositories will be required by the Nuclear Regulatory Commission (NRC) prior to licensing, but this was questioned.

Another kind of criterion that was suggested would pertain to facility design requirements. No consensus was reached, but many persons held the view that such a criterion was not appropriate and is beyond the jurisdiction of the EPA and is under the jurisdiction of the NRC.

INSTITUTIONAL CONTROLS AND RETRIEVABILITY

Does the widely endorsed belief that disposal of high-level waste should be independent of the existence of future institutions necessarily imply foreclosure of "perpetual care" and remedial actions?

To begin with, it was admitted that the phrase in the foregoing question, "widely endorsed," may not be true, but that this should not affect the discussion. It was generally conceded that if retrievability is considered as part of the criteria, it should be done on the basis of safety first and possible new end uses (i.e., economic), secondarily. Additionally, the following observations were made without consensus. Without retrievability, monitoring (i.e., "perpetual care") would be required. We cannot guarantee that future institutions (political, economic, etc.) will exist to "care" for the waste or to conduct adequate surveillance.

Should the environmental protection criteria require, encourage, discourage, forbid, or disregard monitoring or retrievability of waste during the terminal phase of disposal?

Most people felt that retrievability for geological disposal should be encouraged. There was some disagreement. Some pointed out our inability to predict the future. Thus, specific provision for retrievability would help future remedial action in the event of unsuccessful containment. The view was expressed that retrievability must be assured. Others disagreed on the grounds that this could jeopardize initial integrity. It became evident that there are various degrees of retrievability depending on how long after disposal it should be assured. Thus, there could be a range of compromises. Retrievability would not be required in order not to preclude space disposal or transmutation. It was asserted that retrievability had no place in an EPA standard. It was stated that encouragement of retrievability should include a cultural mechanism to provide the information required such as location, etc., perhaps on an international basis. It was pointed out that the decision whether or not to provide retrievability may depend on analysis of accident hazards and waste types.

There was a discussion of the possibility of a meltdown accident, and subsequent catastrophic release with defense opposed to commercial wastes. It was stated that this possibility should be avoided for retrievable surface storage facilities (RSSF). It was asserted that if defense wastes at Savannah River were to be put on the surface, abandoned immediately, and immediately began to leach, the consequences would be a dose to nearby individuals of about 1 percent of background.

The opinion was expressed that monitoring should be carried out. It was also stated that although this is desirable, we cannot depend on future generations to be able to carry out either monitoring or retrieval.

PERSPECTIVES

1. Is it ethical to require high-level waste disposal technology to achieve goals that cannot be achieved for disposal of other forms of radioactive wastes?

2. Conversely, is it ethical not to require for other types of waste the same goals as may be set for high-level waste?
3. How might the EPA relate its activities regarding radioactive waste to its efforts and those of others to control other pollutants?

Consensus was reached that all categories should be treated consistently. The discussion which led to this conclusion included the observation that some extremely hazardous pollutants, such as lead, were neither feared by the public nor regulated by the EPA to nearly the same extent as nuclear wastes.

It was argued, however, that radioactivity, while possibly not uniquely hazardous, has been unique in its historical role in bringing about a cultural divide marking a radically new public awareness of environmental hazards. The public, it was suggested, is responding to the magnitude of the problems involved in the disposal of nuclear wastes and is becoming aware that cleaning up the nuclear industry is only the beginning of solving the environmental crisis.

It was proposed that the proper answer to all three of the above questions lies in criteria structured as follows:

The EPA should establish a "baseline" acceptable risk that management of high-level waste, other radioactive waste, and chemical pollutants would fall below. This risk would be the maximum acceptable risk and would be expressed as, for examples, health effects/person/year, or health effects/megawatt-electric-year of power generation, or health effects/person/ton of toxic chemical produced. The risks should be the integration of consequences times probabilities and should include the full range of events from routine releases through major accidents and natural disasters. The magnitude of the baseline risk should be chosen so that the risk of harm to individuals is the same for high-level waste, low-level waste, and chemical pollutants. The EPA should further require that risks from management of each type of pollutant be reduced below the baseline risk to the extent reasonably achievable, where reasonably achievable is defined as follows: EPA should establish a trade-off value in dollars/expected health effect that is equal for all pollutants. Money should be spent by the responsible industries to reduce risks below the baseline risk, pollutant by pollutant, until the incremental cost of reducing a risk further exceeds the trade-off value. Expected health effect is here defined to be the integral of consequence times probability over all identifiable events.

It is recognized that the final risk resulting from the above procedure will be different for different pollutants. However, the baseline risk and the trade-off value should be the same for all pollutants, and should be obtained through a process of broad public participation such as rule-making hearings. Examples of values that might come forth as acceptable from such public participation could be a baseline risk of one chance in 100,000/person/year of death and a trade-off value of $500,000/expected death. Both the baseline risk and the trade-off value should be constant in time when considering future versus near-term risks.

Consensus was not reached on the above method. Objections raised to this approach included the following:

1. It was contended that probability estimates cannot be scientifically established because of subjective assumptions inherent in such estimates.
2. It was suggested that providing a dollar value for human life is inappropriate; it was also noted, however, that providing a dollar value for human life is implicit in all regulatory standards.
3. It was also contended that no level of injury to human health could be accepted in principle. The constraints are the time and resources that are allocated to reducing risk to zero.
4. An objection was also raised to defining risk as probability times consequences. It was contended that high-consequence events should be treated specially.

SHOULD CRITERIA BE DEVELOPED SEPARATELY FOR WASTES ALREADY EXISTING AND FOR WASTES WE ARE NOT NOW COMMITTED TO GENERATE?

No consensus was reached on this question. The establishment of separate criteria for present and possible future wastes was defended on the ground that it would permit extremely stringent criteria to be established for wastes which we are not yet committed to generate, while realistically providing for means to dispose of present wastes by existing technology along as-low-as-reasonably-achievable (ALARA) principles not acceptable for the long run. This argument was criticized as permitting a lax standard to be set for the present inventory of wastes. It was also seen to be a departure from a principle on which we had seemed to reach consensus, i.e., on treating various categories of waste, i.e., "high-level," intermediate-level," and "low-level" wastes, or radioactive and nonradioactive pollutants by an equally stringent standard of environmental safety. It was asserted that it will be possible in the near future to meet sufficiently stringent standards so that two sets of standards will be unnecessary. The argument for separate criteria was further defended on the ground that the intention was not to permit lax standards now, but very high standards of environmental safety later even though they might make further generation of nuclear wastes cost-prohibitive.

SHOULD INTERNATIONAL CONSIDERATIONS BE WEIGHED IN SETTING CRITERIA AND STANDARDS?

This question was not vigorously argued and no consensus was reached. Among the points that were stated was that, in accordance with the principle that endurance of costs (risks) should be tied to enjoyment of benefits, wastes generated in the U.S. should not be exported for disposal to international territory and that, therefore, such potential disposal options as deep seabed should be ruled out. This principle might be extended to the location of disposal sites near international borders because of the likelihood that the effects of an accident would cross such national boundaries.

On the other hand, a question was raised as to the possible significance of returning large inventories of foreign-generated waste to the U.S. for disposal. Were the volumes likely to be large enough to influence management decisions? How would Americans feel about bearing the costs of such foreign-generated wastes? An opinion was offered that the obligation we would thus undertake would not more than double our commitment. Along other lines, it was suggested that an internationally arrived at and implemented solution to the waste management problem might have the greatest chance of long-term institutional backup. Another consideration was that whatever decision(s) the U.S. makes in regard to the nuclear waste management problem might well affect nuclear waste management methods in other countries.

SHOULD EPA'S STANDARDS BE SET SUCH THAT THE INDUSTRY CAN MEET THEM?

The consensus on this question was "not necessarily." They should be set at a level low enough to protect the health of present and future populations. If an industry is unable to meet standards based on EPA criteria then it should not be in business.

MULTIPLICITY

Briefly stated, the multiplicity issue is should more than one method of storage or disposal and site for storage/disposal be utilized in managing radioactive wastes? Subissues addressed under the multiplicity issue were:

1. Is there a net advantage to pursuing multiplicity of sites?
2. Is there a net advantage to pursuing multiplicity of methods?
3. Should multiplicity of sites be used to distribute risks?
4. Is the concept of required multiplicity consistent with the concept of reducing risks to as low as reasonably achievable?

5. Should control of wastes be strongly centralized?
6. Is required multiplicity of methods or sites an appropriate issue for inclusion in the EPA's forthcoming criteria?

Consensus was reached that there was probably a net advantage to having multiple waste repository sites, but further technical consideration is needed.

Consensus was reached that multiple methods should be considered in managing radioactive wastes but that EPA criteria should not preclude or require multiple methods.

In answer to the question of whether required multiplicity is consistent with the ALARA considerations, consensus was reached that in establishing EPA criteria the baseline level should not be based on ALARA.

In discussing the above issues the following points were raised.

1. Multiplicity of sites is probably a good idea because if one site proves to be unacceptable an alternate site would be available for waste disposal and/or storage. It has the advantage in that a single large event would only affect one site. It has the disadvantage that as the number of sites increases, the probability of release will also increase. Multiplicity of sites would also result in reduced waste transportation, i.e., shorter distances between points of waste production and points for waste storage/disposal.

2. It was suggested that multiplicity of sites could be used to distribute the risks to the persons receiving the benefits. Concern was expressed that the EPA criteria somehow address the problem of discrimination against inhabitants of areas chosen for waste disposal sites whose total environment would be disrupted. Although it was generally agreed that the risks should be borne by the persons benefiting from nuclear power. Arguments against using multiplicity of sites to achieve risk distribution included:

   a. Military wastes cannot be shown to have benefited one geographical location more than another.
   b. Geographical areas relying heavily upon nuclear power may be unsuitable for waste storage or disposal.
   c. Since risks are long-term and benefits are not, the persons bearing the risks would not be the

persons receiving the benefits even if multiplicity of sites were used to distribute risks.

It was asserted that Michigan would not accept a Federal waste repository unless repositories were located in other states also. With regard to multiplicity of methods, there was concern that at the present time the best methods may not be known and the standards should allow for future technological breakthroughs. Requiring multiplicity of methods may be inconsistent with ALARA, since one method may be clearly preferable to its alternatives. It was noted that multiplicity of methods was a concern that will be addressed by ERDA and the NRC in their studies and that alternative methods would be evaluated in individual waste management facility environmental impact statements. It was further noted that were the EPA to address multiplicity of methods in their criteria, it would repeat planned NRC criteria. It was noted that local communities would likely require some form of compensation for allowing wastes to be disposed of or stored within their domain.

The constitutionality of Federal control over waste management was challenged.

SHOULD HIGH-LEVEL WASTE BE DISPOSED OF BY GEOLOGICAL DISPOSAL, BY RSSF, BY OTHER METHODS?

This question was discussed in regard to its relevance for establishing criteria. Two questions were raised: (1) does method make a difference in the criteria set, and (2) does the EPA have jurisdiction in stipulating method in the criteria? It was agreed that the criteria are established first and that the method should conform to the criteria.

In regard to geological disposal, there was no consensus that this was the most desired method. It was pointed out that the ERDA-proposed sites are geological.

In regard to RSSF, one comment was made that no surface storage should have meltdown capability.

Other methods were discussed, including ocean disposal, outer-space disposal, and transmutation.

SHOULD PLUTONIUM BE SEPARATED FROM FISSION PRODUCTS?

No consensus was reached on this question. The arguments on either side of the problem were as follows:

1. Yes. Removal and separate treatment of plutonium will decrease the long-range hazards of high-level waste disposal because the plutonium can be disposed of by burning it in a reactor.

2. No. Separation of plutonium would present the possibility of diversion for weapons or terrorist use. Separation could not physically remove 100 percent of the plutonium so that the long-term risks of high-level waste disposal still remain. Even if plutonium is separated you may have to dispose of it anyway.

It was stated that alternative methods of reprocessing spent fuel for separation of plutonium are being looked into that would produce a product "poisoned" with other elements such that the product could not be used for weapon production.

PRESENT VERSUS FUTURE RISKS

1. Should the criteria and standards for high-level waste address only a selected period of time? What should be the basis of such a selection: decline of the potential hazard due to radioactive decay; other natural processes; or social considerations?
2. For purposes of discussion, which would be the best selection: 100 years? 200 years? 500 years? 1,000 years? Much longer than 1,000 years?
3. Should the selected time period be significantly different for high-level waste, for spent fuel, or for transuranic (TRU) waste?
4. What guidance, if any, should the criteria provide on the relative concern for risks to present (or near-term) generations and to future generations?

Consensus:

The basic safety criteria for environmental protection should address an unending period of time. However, it was not clear that safety for future generations would be greater or less than for present ones because of uncertainties in projections of the long-term effectiveness of containment systems.

Discussion:

Some conferees argued that future generations will benefit as much as current ones from the production of electricity through nuclear power, while others felt current generations should bear a greater burden of the risk.

It was stated that models of population growth, electricity consumption, uranium mining, power plant operation, and radioactive waste decay indicate that total radioactivity from the fuel cycle will decrease in a few hundred years so that future generations will be subjected to less severe potential consequences than current ones.

One view was that sound engineering judgments cannot be projected for more than 1,000 years (about 30 generations) considering engineered and natural barriers; hence, retrievability is needed for insurance, and international cooperative approaches are needed to achieve societal coverage.

Incremental funds that might be spent now for decreasing the already minimal risks could be better applied to social improvements and benefits for later generations. Some reservations were expressed that such logical and beneficial allocations would probably not occur.

It was maintained that there should be no time limit for expiration of basic safety criteria for high-level waste, spent fuel or for TRU waste, but it was recognized that these criteria could be revised in the light of future developments, including possible changes in technology.

Basic safety criteria should be established on the basis of health and environmental protection, including public acceptance--not on an as-low-as-reasonably-achievable basis.

It was suggested that prior to formulating criteria EPA make an economic study into possible alternate ways of life that would not require nuclear energy, and that the results might affect the formulation of basic safety criteria.

CONCLUSION

In summary, consensus on the answers to questions was reached in a few cases, more often there was disagreement and, importantly, this disagreement was not merely of a dualistic nature but was multifaceted. The questions offered in the Issues and Objectives Statements raised other questions, which often required answers necessary to answering the original question. Consideration was given to how or if the EPA criteria should include such categories as unplanned or accidental events, institutional controls and retrievability, multiplicity of sites and methods of waste management, present versus future risks, as well as to what perspective is appropriate when considering high-level versus intermediate-level versus low-level radioactive wastes and when considering radioactive wastes versus other, in some respects equally hazardous, wastes.

Those issues on which the group came to a consensus were:

1. The criteria should apply to waste management, not merely waste disposal, since transportation to disposal sites and retrievable phases of the disposal process might not otherwise be considered.
2. All unplanned and accidental events, regardless of their probability of occurrence, should be considered by the EPA in setting criteria.

3. All waste categories (including high-level, low-level, and intermediate-level radioactive waste and nonradioactive wastes) should be treated consistently.
4. There will probably be a net advantage to having multiple waste repository sites, but further technical consideration is needed.
5. Multiple methods should be considered in managing radioactive wastes, but EPA criteria should not preclude or require multiple methods.
6. The EPA criteria should not consider technical feasibility in setting standards, and the standards should not be based on ALARA concepts. Instead, the standards should consider environmental safety exclusively.
7. The basic safety criteria for environmental protection should address an unending period of time.

The issues for which no consensus was attained are many and varied, and serve to illustrate the complicated and extensive problems associated with establishing criteria for radioactive waste management.

TOPIC 1 EXECUTIVE COMMITTEE

POLICY AND TECHNICAL CONSIDERATIONS FOR HIGH-LEVEL RADIOACTIVE WASTE

NAME	AFFILIATION
Dale H. Denham	Lawrence Livermore Laboratory
Linn Draper	University of Texas
Daniel Egan	Environmental Protection Agency
Margaret Farrell	Citizens Against Nuclear Threats
Jim Feeney	New Mexico Public Interest Research Group
Bill Hewitt	Nuclear Regulatory Commission, Waste Management Program
Judith Hurley	Rocky Flats Action Group
Stanley Lichtman	Environmental Protection Agency
W. A. Lochstet	The Pennsylvania State University
Lee Lockie	New Mexico Environmental Improvement Agency, Air Quality Division
Thomas McGarity*	Office of the General Counsel, EPA
Wendy Macpherson	Texas Water Quality Board
N. Sonenshein	Assistant to the President, Global Marine Development, Inc.
S. V. Topp**	E. I. du Pont--Savannah River Laboratory
Richard E. Webb	Midwest Environmental Protection Association

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* Moderator.

** Panelist for Plenary Workshop Session, 12 April 1977.

RESPONSE OF WORKSHOP PARTICIPANTS TO SUMMARY AND CONCLUSIONS OF WORKING GROUP 1

THOMAS O. McGARITY (Environmental Protection Agency (EPA), Washington, D.C.): The first question is from Marc Goldsmith.

MARC W. GOLDSMITH (Energy Research Group, Framingham, Massachusetts): The inclusion of accidents and unplanned events in the EPA environmental criteria development for high-level waste is inconsistent with EPA's standard-setting role with respect to the NRC [Nuclear Regulatory Commission] role. What was the logic by which consensus was arrived to include accidents in EPA's high-level criteria?

McGARITY: Is there anyone who wants to talk about that? I think that was a general discussion from everyone. I think the rationale was it is probably just a difference of interpretation from your interpretation of what the roles are.

GOLDSMITH: If I understand correctly you cannot do an accident analysis unless you know a site-specific or equipment or technical-specific kind of thing. EPA's role according to 40 CFR 190 and the program statements and the Federal regulations that cover EPA standard setting criteria is to set overall environmental criteria, not specific site criteria or specific equipment criteria, and that is inconsistent.

McGARITY: We certainly discussed that dichotomy and the two roles thoroughly. I think that the distinction to be drawn as I recall that people were careful to make is...there was consensus that they should be considered, there was not consensus on how EPA should address those. So you may be pointing out some problems with the latter, about which there was no consensus. The next comment is from Deborah Grout.

DEBORAH GROUT (University of New Mexico, Albuquerque, New Mexico): EPA must not rely solely on regulations. It must be able to impose fines and fees on industries that do not abide by EPA standards (for whatever reasons). These fines must be large enough to adequately represent the damages caused by failing to meet EPA standards.

McGARITY: Did you want to ask a question?

GROUT: I just wanted to make that comment because of the past history EPA has had in trying to enforce their standards strictly through regulations.

McGARITY: The next comment is from William Remini.

WILLIAM REMINI (U.S. Energy Research and Development Administration, Washington, D.C.): On page 1-1 of the Preliminary

Preceding page blank

Draft of the Summaries and Conclusions [page 1-80 of this document], an objection is cited to the association of radioactive waste with "value."

McGARITY: As you noticed by the way that has been changed. The sentence now reads, and maybe this will clarify your question without having to go any further, "an objection was also made to the semantic implications of the terms high-level and low-level and that they might misleadingly imply relative importance." Does that answer your question? Okay. The next comment is from John Klucsik.

McGARITY: The next comment is from Arthur Byrnes.

ARTHUR BYRNES (Citizen, Albuquerque, New Mexico): Everyday living involves a risk to one's well-being. In the United States, for example, a tremendous danger involves gasoline, with which millions of persons have some contact daily. Gasoline is now an accepted risk. Our scientists have landed persons on the moon and brought them back--an outstanding achievement. I tend to rely on their ability to handle all facets of nuclear development with regard to safety factors. Other countries are developing nuclear programs. Let us get going on it and trust our engineers.

My comment relates to Working Group 3.

McGARITY: O.K. I'll give it to Dick [Denney] then. The next comment is from John Klucsik.

JOHN KLUCSIK (U.S. House Committee on Interstate & Foreign Commerce, Washington, D.C.): Please elaborate constitutional challenge to Federal ability to regulate radioactive waste disposal.

McGARITY: That was made by Dick Webb. I offered him, although it was not entirely relevant to our considerations, an opportunity to read his statement on that. If you have that statement you could very briefly say what you meant.

RICHARD E. WEBB (Midwest Environmental Protection Associates and Mapleton Intervenors, Toledo, Ohio): I have concluded that you cannot prove that reactors are safe or unsafe or waste is safe or unsafe. It is going to depend on subjective judgments and therefore it will depend on who decides. We are therefore going to have to take care to make sure the proper authority in society makes that judgment. In other words it will depend on which set of individuals, and to find that answer would require recurrence to the Constitution and that is elaborated where I conclude that the nuclear program is unconstitutional, that the people never gave the Federal government a power to provide for the general welfare on which they are using to build nuclear energy. Therefore, it would mean Congress should review the nuclear programs, and, if they want to continue with it, they are going to have to come back to the states and ask for the authority, and the people will elect delegates to state conventions, and in those state conventions each state will have to decide. It will take three-fourths of the states. That is elaborated in my legal brief, in my book published by The University of Massachusetts Press, entitled The Accident Hazards of Nuclear Power Plants. Thank you.

McGARITY: The next comment is from F. R. Krause.

F. R. KRAUSE (Sandia Laboratories, Albuquerque, New Mexico): Plutonium separation. Without plutonium separation, increased uranium production will deplete domestic resources by approximately year 2000. Future generations need the option to reprocess spent fuel and other wastes to balance environmental and war risks. Criteria should address "measure of effectiveness." Acceptable risks should be the subject of individual and regional choice.

McGARITY: Did you want to ask a question or is this just a comment for the record?

KRAUSE: I would like to make a comment which goes back to the question my children asked me on tobacco. They see on TV that statement that tobacco is hazardous to your health. They ask me, "Daddy, why isn't it banned?" We explained to them that if you grow up and mature we are a society which has a freedom of choice. And people retain that choice of what is an individual's and society's acceptable risk. This is even more so in this particular question, where you have to balance the risks of health and environmental [considerations] against the risks of war, the lack of energy resources.

McGARITY: The next comment is from Gladys Winblad.

GLADYS WINBLAD (Citizen, Albuquerque, New Mexico): As regards unplanned and accidental events, I would like to see a couple of examples of these included, such as the intrusion of saboteurs or terrorists.

Yes, I think that the way it is written, "unplanned and accidental events" sounds extremely innocuous, whereas this is very serious. Terrorism is serious, leaking into ground waters is serious. I think it would emphasize the seriousness of these things.

McGARITY: What you just said will be in the records. The next comment is from L. John Cooper.

L. JOHN COOPER (Nebraska Public Power District, Columbus, Nebraska): The statement was made that all levels of waste be treated uniformly. Should this have been that equal risks should receive equal treatment?

McGARITY: I think that that was what was meant. Does anyone disagree with that? I think that was generally what the feeling was. The next comment is from Jack Briggs.

JACK BRIGGS (Citizen, Anchorage, Alaska, and Raton, New Mexico): Are there any plans to put nuclear waste sites in Alaska (especially near the new Capitol site)?

McGARITY: Well, we did not discuss this in the working group.

BRIGGS: Do you have the answer from another source?

McGARITY: If somebody in the room has an answer, I expect they could provide it.

H. CLYDE CLAIBORNE (Union Carbide, Office of Waste Isolation, Oak Ridge, Tennessee): Yes, Alaska is located in what we call a high seismic risk zone, high tetonic activity, and we would not consider putting a waste repository there as I see it now. I certainly personally would be greatly against it.

BRIGGS: Thank you. Ladies and gentlemen, the first comment I would like to make is the very idea of trying to influence the people of New Mexico with the idea that there is going to be full public hearings and full public input into a serious question, the question as serious as the nature of dumping radioactive wastes in New Mexico--the whole idea is ludicrous. How many do we have in here--less than three hundred. How many did you have at your last meeting? What I am saying is that...no wonder Russell Train left the EPA. I am very pleased that the EPA is here trying to do what they are trying to do. I am not trying to say anything derogatory about the young people here or the older people here who are trying to get through this problem. But let me state very clearly this, and that is that by accepting the premise that we have to do something about this nuclear waste in the way in which EPA is accepting that premise, is more or less conceding that the generation of nuclear waste is necessary. Now, that just is not the case.

McGARITY: We have a couple more comments we would like to get in...

BRIGGS: Exactly as I expected, I will be cut short. Many other people will be cut short. Now the people of New Mexico had better get on the ball. Just yesterday 60 miles south of Cimarron where they are planning to dump so called low-level nuclear waste, I heard a comment that, "Aren't we ever going to get a vigilante committee going; we'd better." Are we going to have to choose between a vigilante committee and people like Bill Perkins who have the audacity and arrogance to get up and say that the nuclear unholy trinity--Congress, the executives, the nuclear industry and the nuclear bureaucracy--that those people should tell us what we are going to receive in our so-called free press. God help us.

McGARITY: I did not mean to cut you short. If you would like to write something up in virtually any length you want to write, we will put it in the record.

Let me read something by the way into the record. It is a telegram we received, and this says "We 29 members of Beta Sigma Phi sorority regret that we are unable to attend this EPA seminar. We are concerned about any possible contamination of our underground water tables which we in the Texas panhandle rely quite heavily upon. In comparison to other parts of the country our land is relatively free from the horrors of pollution and we do not want to risk spoiling it. We are using this telegram as a means to extend to you our feelings of opposition towards the possibility of utilizing any part of the Palo Duro Canyon as a site for nuclear waste." That is from the Beta Sigma Phi Mu Gamma Chapter. The next question is from Gary Armstrong.

GARY ARMSTRONG (NON, Albuquerque, New Mexico): In this statement it was countered that probability values could not be scientifically demonstrated--that they would depend on subjective component probability values (guess), but that all that could be done is to make a judgment of likelihood on the basis of objective information. What is the difference between "probability values" and "judgment of likelihood on the basis of objective information?"

McGARITY: The commenter who made that was Dr. Webb, so I guess he can...

WEBB: A numerical probability value is like one in ten billion. Somebody makes some estimates and guesses some figures and puts them together. That is called subjective probability values, or that is probability values, numeric. Making judgments on likelihood based on objective information is to learn all of the different possibilities that are conceivable, that cannot be ruled out as impossible, and those that you know are fairly possible as well, and calculate the consequences and understand the various things that would have to happen in order for the radioactivity to get out into the groundwater in our food chain. Knowing those facts, objective facts, then you just make a judgement whether you want to generate the waste or not. That is it.

McGARITY: Thank you. The final question here is from Robert F. Williams.

ROBERT F. WILLIAMS (Electric Power Research Institute, Palo Alto, California). In suggesting that EPA criteria should consider "environmental safety" exclusively, and not technical feasibility or as-low-as-reasonably-achievable (ALARA), in setting criteria have not we substituted a difficult, if not impossible, test in developing criteria? Specifically the term "environmental safety" must be defined. Second, instead of the value of one man-rem, must we establish an even more arcane calculus. How many louseworts are equal to one grebe? Anyone want to answer that, particularly the last one? I think the serious question was if we throw out technical feasibility and we rely entirely on environmental safety, what in fact are we relying on? Does anyone want to address that?

DAN EGAN (Environmental Protection Agency (EPA), Washington, D.C.): The only answer I think we can offer as a working group to that is we asked the question and did not reach a resolution as to what that should be, but that that should be the framework in which EPA should set its criteria. The addressing of what the specific meaning of what environmental safety [is] or what units or method you would choose to stipulate that is unresolved.

McGARITY: Thank you. That concludes our discussion on Working Group I.

TOPIC 2

POLICY AND TECHNICAL CONSIDERATIONS FOR INTERMEDIATE-LEVEL AND LOW-LEVEL RADIOACTIVE WASTE

TOPIC 2: POLICY AND TECHNICAL CONSIDERATIONS FOR INTERMEDIATE-LEVEL AND LOW-LEVEL RADIOACTIVE WASTE

INTRODUCTION

The category of low-level and intermediate-level radioactive waste is generally understood to include those radionuclides of both short and long half-lives, including transuranics,* which by virtue of their activity, radiotoxicology, or form are currently considered to be amenable to disposal on or near the surface of the earth within certain engineered and environmental barriers. It includes wastes from most operations of the uranium fuel cycle and wastes from commercial, research, medical, and government sources. These wastes vary widely in composition and radioactivity and are a function of the operations that generate them.

Materials that are normally disposed of in shallow land burial have been classified by the Energy Research and Development Administration (ERDA) as "solid radioactive waste other than solidified high-level waste." Included in this classification are such diverse materials as paper, rags, rubber, wood, glassware, carcasses and excreta of experimental animals, protective clothing, small pieces of contaminated equipment, rubble from dismantled buildings, and irradiated components. These wastes, except for the last named, are contaminated with various radionuclides such as cobalt-60, tritium, strontium-90, cesium-137, radium-226, and, at some sites, transuranics.

Also included in the low and intermediate category are those wastes resulting from the mineral extraction and processing industry. Significantly elevated concentrations of the primordial radionuclides have been found to be generally associated with byproducts and wastes from the mining and milling of uranium and phosphates.** Similarly, elevated concentrations have also been noted for certain deposits of copper, western coal, bauxite, and petroleum brines, which, when extracted, have the potential of exposure of the public through their waste materials.

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* Transuranics have been limited by five of the six commercial sites to less than 10 nanocuries per gram.

** Ra-226 concentrations in uranium mill tailings commonly range from 700 to 800 pCi/gram (Swift et al. 1976a). For phosphate mining and beneficiation, average Ra-226 activities of 45 pCi/gram for slimes, 33 pCi/gram for byproduct gypsum, and 56 pCi/gram for ferrophosphorus slag have been reported (Ref. 5). See Appendix A.

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In addition to typically lower activity, these radioactive wastes differ from others in the low and intermediate category by virtue of their large volume. The average uranium mill tailing pile occupies about 35 acres of land. All inactive tailing piles account for a total area of approximately 1,000 acres and a total mass of approximately 17 million tons. An Environmental Protection Agency (EPA) survey has shown an average radon-222 exhalation rate of 2,900 Ci/year for one inactive unstabilized pile of 35 acres, with a total rate of 6×10^4 Ci/year for all such piles (Ref. 6). The population within a distance of ten miles of these sites numbers over half a million, with a majority of these people residing in the vicinity of the Salt Lake City and Grand Junction piles (Ref. 3).

The phosphate industry, too, is notable for the vast quantities of waste discharged. The major phosphate byproduct, phosphogypsum, contains elevated concentrations of radium-226. With an annual producton rate of this byproduct of 23 million metric tons a year, the country's total cumulative production now exceeds 300 million metric tons, half of which has been generated since 1970 (Ref. 2). Assuming an average source term concentration of 33 pCi/gram as measured by Guimond and Windham (Ref. 5), this correlates with an annual radium-226 extraction rate of about 800 curies.

POTENTIAL IMPACTS AND CONTROLS

Because of the diversity of waste generating activities, waste forms and characteristics are quite variable. As a result, several disposal concepts considered feasible or already in use include: (1) surface--for mill tailings, slimes, and overburden; (2) near surface--for low-level wastes; (3) deep geological--for high-level or low-level waste contaminated with transuranics. To date, control of low-level and intermediate-level waste has been limited to temporary storage, placement in the ground, and ocean disposal. With the exception of ocean disposal, these activities have taken place at laboratory or test sites owned or operated under the jurisdiction of the Federal government.

There are six licensed commercial burial sites, as shown in Figure 1: Sheffield (Illinois), Morehead (Maxey Flats, Kentucky), Beatty (Nevada), West Valley (New York),* Barnwell (South Carolina), and Hanford (Washington). Proposals have been made for additional sites in several other states, but none have yet been approved.

The activity of most of the low-level wastes buried at these sites is greatly reduced in a relatively short time period

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* Site closed.

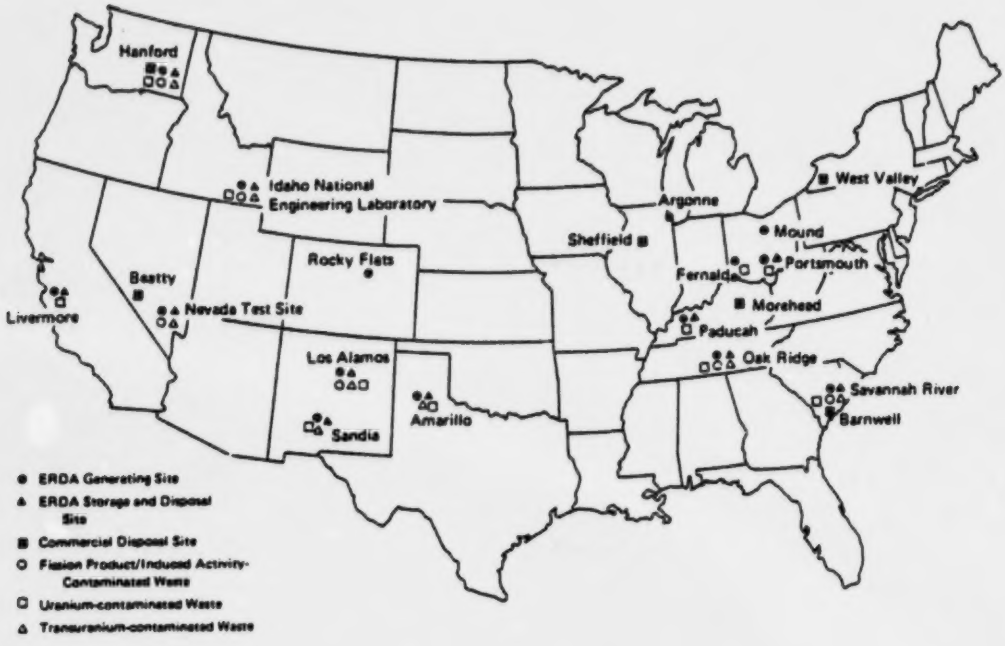
Hanford
Idaho National Engineering Laboratory
West Valley
Argonne
Mound
Sheffield
Rocky Flats
Beatty
Nevada Test Site
Livermore
Fernald
Portsmouth
Morehead
Paducah
Oak Ridge
Los Alamos
Amarillo
Sandia
Savannah River
Barnwell
● ERDA Generating Site
▲ ERDA Storage and Disposal Site
■ Commercial Disposal Site
○ Fission Product/Induced Activity-Contaminated Waste
□ Uranium-contaminated Waste
△ Transuranium-contaminated Waste

Figure 1. Major generating storage and disposal sites for solid low-level radiative wastes. The West Valley, New York, site has been closed (Ref. 1).

(in terms of radioactive waste disposal). As shown in Figure 2, this time period is approximately 100 years. Thus, for the long term, only those sites containing significant concentrations of uranium series radionuclides (including radium) and transuranics will be of concern. An analysis of the time dependence of the total activity after site termination was performed for the Maxey Flats burial site in Kentucky by Gat and Thomas (Ref. 4), as shown in Figure 3. The waste material at this site encompasses the whole isotopic spectrum, including various fissile and special nuclear materials.* As the graph shows, assuming the inventory is not removed from the site, 90 percent of the total activity will have decayed in about 175 years. For sites containing little or no transuranic or other long-lived waste, the "site decay time" would be even less. These figures, of course, do not include decommissioning wastes. Decommissioning wastes include removable contaminants and facility structures and topsoil, if contaminated. Unlike high-level waste disposal, then, the environmental impact of low-level sites containing only shorter-lived materials would be of concern over the first century or so after termination of site operations. The impact is primarily a function of both the site integrity and the waste materials involved (half-lives, radiotoxicity, environmental transport coefficients, etc.).

Uranium mill tailings and phosphogypsum contain most of the decay products of uranium and some residual uranium. The principle radionuclides of concern, in order of their appearance in the decay chain, are thorium-230, radium-226, radon-222, polonium-218, lead-214, bismuth-214, polonium-214, and polonium-210. Uranium mill tailings and phosphogypsum piles release airborne radioactivity as radon gas and also as airborne particulates. Radioactivity may be leached from the waste piles by precipitation or by surface runoff. The radioactivity in the uranium mill tailings is also sufficient to create a field of gamma radiation in the vicinity of the tailings. Because of the large mass of waste material, control for uranium mill tailings to date has been limited to surface stabilization, although for some sites (such as the Vitro site in Salt Lake City), removal has been proposed.

In general the impact level associated with tailings or mining residues would be continuous for thousands of years because of the presence of uranium, thorium, and radium. Although the

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* Special nuclear materials (from 10 CFR 20.3 [16]): (1) plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and other material that the Nuclear Regulatory Commission determines to be special nuclear material but does not include source material; or (2) any material artificially enriched by any of the foregoing but does not include source material.

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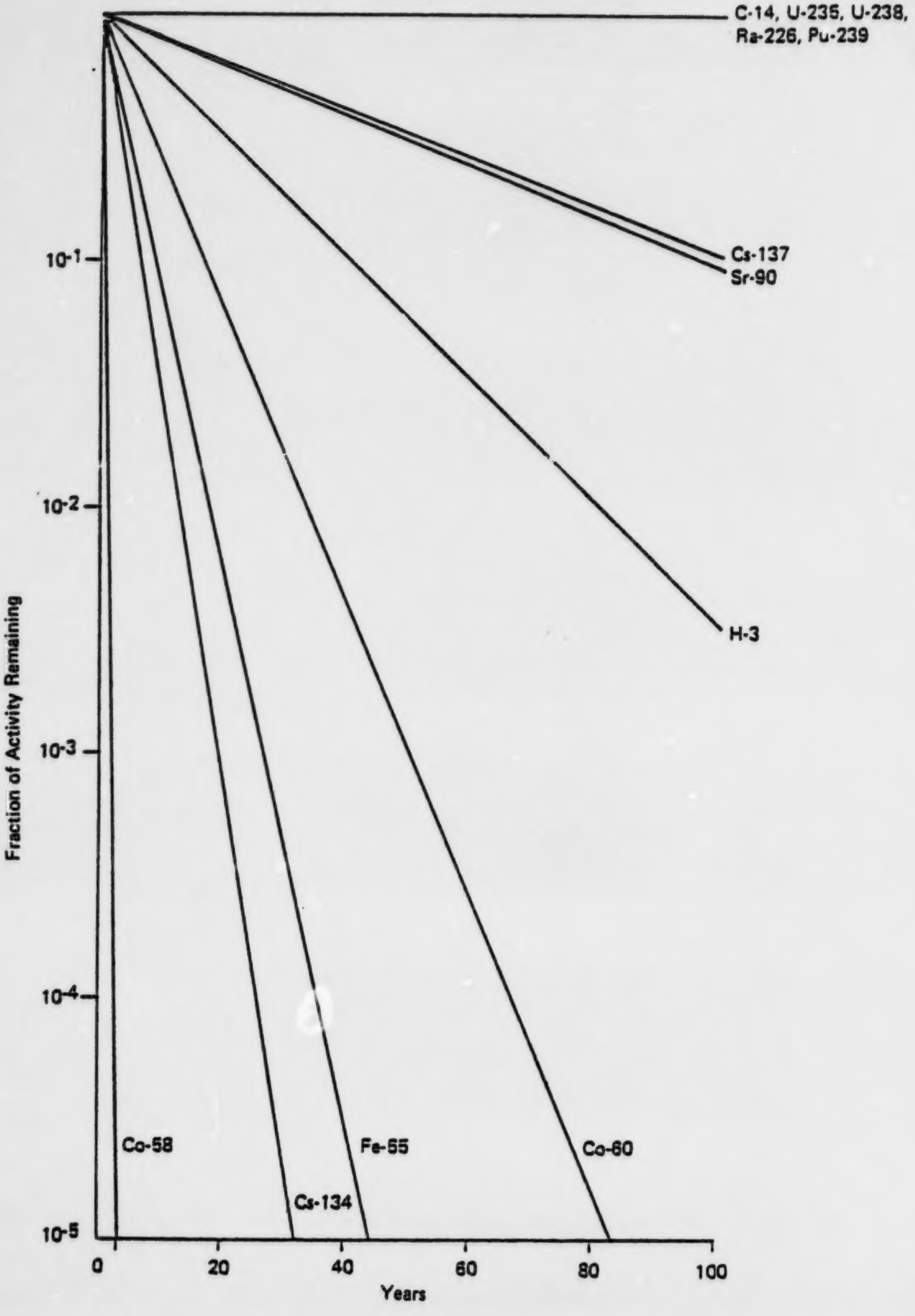

Figure 2. Decay curves for radionuclides prevalent in low-level radioactive waste disposal.

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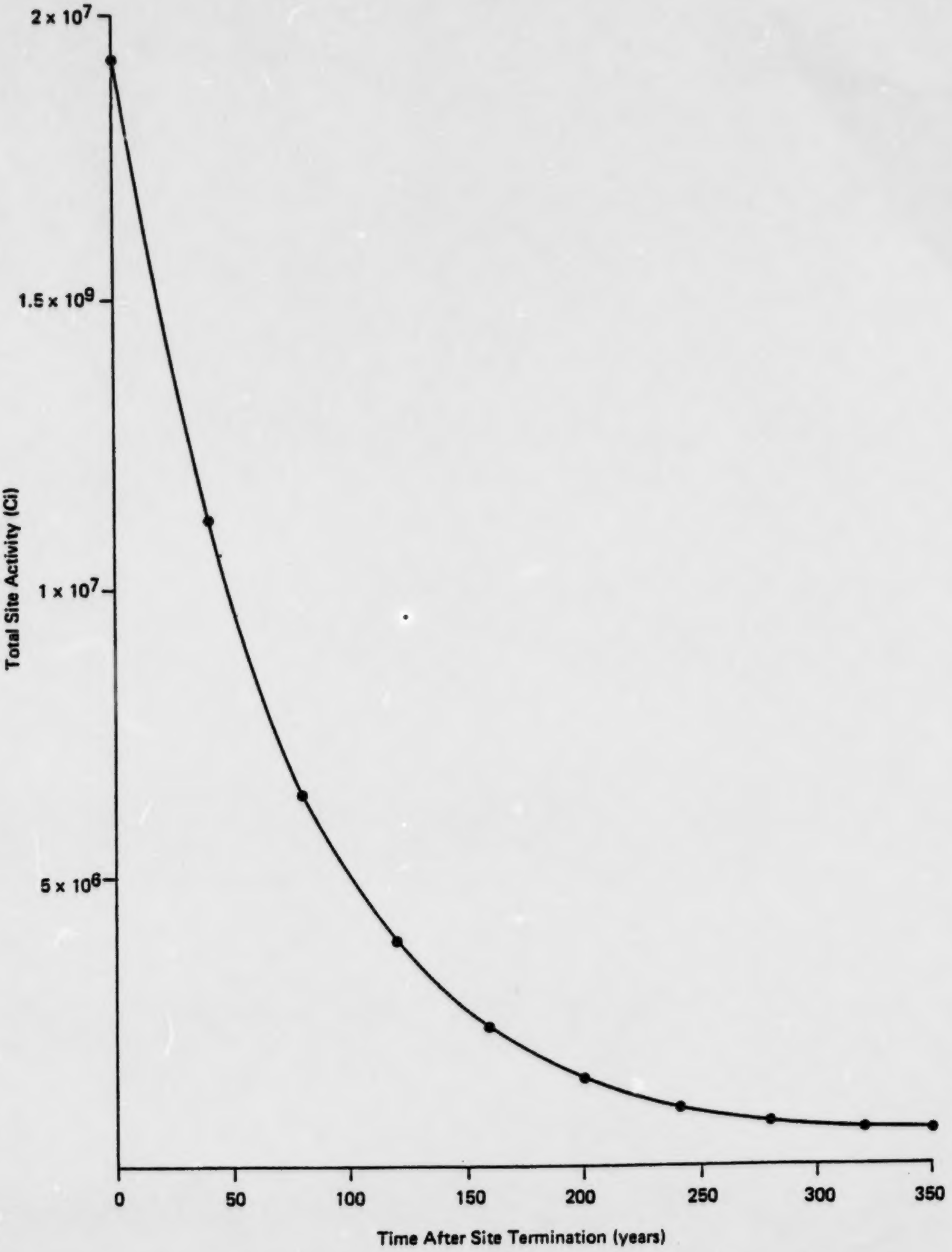

Figure 3. Projected site activity for a low-level radioactive waste burial site (Ref. 4).

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direct and gaseous radiation levels result primarily from short-lived materials, these are in equilibrium with the long-lived alpha emitters and thus are essentially a perpetual source of such materials and their resultant impact. It is likely that current disposal on or near the surface would result in higher environmental levels some years in the future because of erosion, deterioration of stabilization media, and either inadvertent or accidental translocation.

CRITERIA DEVELOPMENT CONSIDERATIONS

The issues in this paper are addressed in the context of low-level and intermediate-level waste, although a number of them can be construed as applying to all waste types. In this manner, it will be possible to delineate inconsistencies among waste types and characteristics and to focus on the state-of-the-art disposal methodology for each waste type as it bears on developing applicable criteria. This discussion is divided into three topical areas: applicability of criteria; near-surface disposal; and surface disposal: naturally radioactive waste materials.

Applicability of Criteria

In the working group addressing approaches to radioactive waste management criteria development at the Reston Workshop, a consensus was reached that, regardless of the type of radioactive waste, the form of the criteria should be applicable to any exposure of people, that is, it should be generic for mitigating risks due to radiation exposure. A number of participants, however, expressed the view that although the criteria should result in such "umbrella-type" numerical standards, these criteria should also require the application of cost-effectiveness to reduce risks for specific sites, methods, or wastes. The question is, then, whether such generic standards are workable for low-level and intermediate-level waste (or for that matter, the broad spectrum of wastes in general), and if so, whether such cost-effectiveness analyses should be performed on each type of waste.

Due to the diversity of waste generating activities, waste forms and characteristics are quite variable. Because of this nonuniformity, their categorization to date has been generally inadequate. If we are to treat the different materials presently designated as low-level and intermediate-level waste, and determine the segregation, packaging, and engineering controls necessary for final disposition, we should better define the physical and chemical characteristics of the materials. It has also been suggested that, instead of definitions, what is needed is merely a methodology by which acceptable categorization could be achieved. Three possible means of categorization are degree of hazard, historical-legal bases, and disposition methodology (e.g., shallow land burial, entombment, etc.), the first two of which have been most widely applied. The issue, then, is whether the criteria should be based on any categori-

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zation by waste type, and if so, by what methodology (activity, half-life, etc.)?

An issue of importance for waste disposal in general, but for low-level disposal in particular, is how to address existing disposal sites in the environmental protection criteria and standards. The performance of low-level radioactive waste disposal systems has not been uniformly good to date; this raises serious questions regarding the future use of such systems and their adaptability to other potentially dangerous waste problems. However, current disposal practices do not appear to have led thus far to any exposure of populations to hazardous conditions. In addition, current disposal sites are under surveillance, with programs underway to upgrade and maintain them to prevent any undue hazard to the environment and the public from developing.

Near-Surface Disposal

Near-surface disposal of radioactive waste is especially relevant to a discussion on criteria development for all wastes. Through the operation of a number of commercial and governmental burial sites and the imminent decommissioning of one such site, extensive experience has been gained in this area. It is necessary that issues be addressed in the context of this experience and that recognition be given to the complexity of the waste types involved.

The relative importance of environmental barriers such as geological formations versus engineering controls, such as matrices and containers, was one of the issues addressed at the Reston Workshop. The consensus of the participants was that the barrier provided by a geologic formation was more important when considering long-term security for all types of waste. However, there are situations that can be envisioned where engineered controls may be necessary, such as in the containment of high-level and transuranic wastes. Until recently, it was generally believed that the disposal of low-level radioactive wastes by landfill burial was a simple, safe, and inexpensive methodology. Sites were selected with geologic and hydrologic characteristics that, it was believed, would provide an environmental barrier sufficient to assure that radioactivity would not migrate from the sites. In addition, the sorption properties of the soil were expected to trap and retain any radioactivity leached from the wastes. There are recent indications, however, that under certain circumstances, particularly in the generally humid climate of the eastern United States, the shallow land disposal of radioactive wastes was not performing as anticipated. Offsite contamination resulting from groundwater seepage and leaching of waste material was detected at a number of sites.

Engineering controls or barriers, in contrast, are more environmentally independent and can be an integral adjunct to maintaining the integrity of a waste disposal site for the required period of time. The question is one of determining the basis upon which the relative importance of these two types of barriers should be weighed, and what the possible "tradeoffs" may be.

A related concern is the geographic location of disposal sites. Are the relative advantages of the geology of drier regions great enough to support the tradeoff between the reduced risks at such sites versus the increased risks and costs associated with the transportation of wastes to such regions, since they are not generally produced there? Is such a reapportionment of risk justifiable, since the few regions of the country satisfying the geological requirements for disposal will receive a disproportionate share of the waste?

Another question bearing on criteria development is whether disposal sites should have a rated capacity for radioactivity that should not be exceeded. A recent report from industry recommends digging deeper trenches and concentrating the wastes as a means to increase burial capacity. Alternatively, an international organization recommended limiting disposal capacity by setting specific limits, dependent upon site characteristics, for the radioactivity that could be buried at each site.

An overriding issue of concern with regard to criteria development for low-level and intermediate-level waste is the basic radiation protection objective in the disposal of these wastes. Should disposal be based on the premise of "as low as feasible" or "as low as practicable," or should the objectives be tailored to fit each specific type of waste? Since the range of waste types includes high-activity, long-lived materials (transuranics),* low-activity, long-lived materials (uranium mill tailings and phosphate wastes), and high-activity, short-lived materials (cobalt-60, strontium-90), it is apparent that the underlying factor is the associated risk, and that a determination should be possible through risk analysis (cost-benefit, risk-cost, etc.).

A related issue is the segregation of wastes by these and other characteristics so that both natural and engineered control can be enhanced. The long-lived transuranics, for example, could be extracted and disposed of in the same manner as high-level waste material. The remaining waste would be less hazardous and would be amenable to more conventional means of containment. The question is, then, whether segregation is an advantageous method of risk reduction to the population, and if so, whether it is cost-effective.

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* Materials with these characteristics have been emplaced at some existing near-surface disposal sites.

A question reflecting the long-term implications of low-level waste disposal in contrast with those of high-level wastes is the length of time for which isolation can be assured for surface burial of radioactive wastes. Should we depend on institutions to maintain the integrity of sites during this period of time? If the time periods in question are long enough, perhaps such dependency is not feasible. If such criteria were found practical, it is apparent that some prescribed limit on the types of waste and activities would need to be established for such disposal. The problem of incorporating naturally occurring wastes into this control mechanism would also be an issue which could achieve resolution via underground disposal in mines or excavations, although the practicability of such measures must be assessed.

The problem or question of retrievability and/or exhumation is one of particular relevance. Should low-level and intermediate-level radioactive waste be disposed of with the intention of future retrievability? If not, retrieving this waste could then be a potentially more hazardous operation than not recovering it. From the opposing side of the question, the issue is whether justification exists for expending resources to make this option available in the first place. It has been suggested that increased land value would be one possible justification. In addition, there is some question whether the technology exists to assure retrievability over an acceptable time period.

One issue which has gained special relevance recently with the closing of the West Valley site in New York is whether a site should be decommissioned, and, if so, in what manner and for what length of time should surveillance be provided once operation has terminated. There is uncertainty regarding the full long-term radiological impact on the environment surrounding this particular site, so monitoring of some type will be necessary for the foreseeable future. Nevertheless, some policy concerning a proper monitoring program for new sites will be necessary. Whether sufficient data is available to make such a decision at this time is a question that needs resolution. Another problem is how to provide for potential difficulties during and after decommissioning. Today, when a commercial site is filled, the responsibility of the licensee operator ceases, the facility is decommissioned, and long-term care falls to the state government, few of which can be said to be totally prepared, either financially or otherwise, to shoulder the implied conditions of long-term care. Whether these functions can be adequately performed by any blend of authority within the Federal system is in need of examination.

The necessity of remedial action levels for environmental contamination is an issue which has some relation to the preceding one. It is important to include those levels at which actions will be taken and what those actions will entail in the monitoring programs. In the context of legacy considerations, the overriding question is whether the availability of remedial measures should be preplanned, or whether, because of the nature of the waste involved and the possibility of institutional instabilities in the future, this approach should be avoided. As with retrievability, there is some uncertainty whether the technology exists for such action, whether it would be cost-effective, and whether such action would, in fact, increase the risk of environmental contamination.

Surface Disposal: Naturally Radioactive Waste Materials

For low-level natural wastes, a number of issues need consideration. These deal mainly with the long-term deposition of uranium mill tailings and phosphate byproducts. Because of the volume of existing wastes, these issues should be considered in the context of present and past practice.

Uranium mill tailings have, to date, been stored adjacent to milling operations. Little or no stabilization has been undertaken to prevent particulates being windblown from tailings piles. Radon exhalation from the piles occurs due to the presence of Ra-226, but the impact to the surrounding population is uncertain. Similarly, phosphate slimes, slags, and byproducts such as phosphogypsum are being stored indefinitely in ponds, piles, and waste pits. There is an overriding issue of determining the ultimate disposition of these wastes. In view of their low-level long-lived activity and the quantity involved, stabilization via chemicals, surface ground covers, and vegetation are possible options for particulate control. Serious questions arise, however, about the long-term implications of bequeathing wastes stabilized by any of these means. Certainly the activities of man and the natural activities of the earth would eventually breach such control.

If stabilization is the only alternative used for disposal, who should have the legal and financial responsibility for the implementation of control measures and the maintenance of waste sites? Normally, the respective states would have jurisdiction, although past and present Federal involvement has made the lines of authority less distinct. The determining factor appears to be the availability of resources, which becomes of paramount importance in those states with numerous waste sites (e.g., Colorado, New Mexico, and Florida). In such cases, should there be a Federal role, and if so, to what degree?

Related to the question of responsibility is the issue of utilization of waste sites. In Florida, thousands of acres of reclaimed phosphate mining land are currently available for unrestricted development. Because of the strip mining methods employed, much of this land has elevated concentrations of radium at or near the surface. Exhalation of radon, a gaseous decay product of radium, through the foundations of structures built on this land has resulted in increased radiation exposure from elevated indoor radon daughter concentrations. A similar situation exists in Grand Junction, Colorado, where uranium mill tailings were used as fill around home foundations. At issue, then, are the measures that should be taken to regulate the usage of low-level waste disposal sites. How can knowledge of the radioactivity of this material be passed on to future generations (as suggested at the Reston Workshop)?

Utilization of waste materials for purposes other than their radioactivity is an issue unique to the low-level waste category. Because of the massive amounts of waste available and their favorable physical and chemical properties, materials such as uranium mill tailings, phosphogypsum, and phosphate slag have been and are being used in a variety of commercial applications, primarily in the construction industry. As technology progresses, such use will become even more likely. How should these materials be addressed under the criteria to be developed?

SUMMARY OF CONSIDERATIONS

This section has addressed issues, topics, and considerations related to low-level and intermediate-level wastes that are basic to developing and establishing environmental radiation protection criteria for radioactive wastes. Although other topics and issues may also be relevant, the presentation was designed to facilitate discussion and evaluation of at least the following areas:

Applicability of Criteria to Low-level and Intermediate-Level Wastes

1. Should the criteria uniformly mitigate risks caused by all radioactive wastes, including low-level and intermediate-level wastes?
2. How should existing disposal sites be addressed in the criteria in order to protect both present and future generations?
3. Should the criteria be based on waste categorization, and if so, by what methodology (activity, half-life, waste form, etc.)?
4. How should the proposed criteria address the present and future use of waste materials?

Criteria Considerations for Sites

1. For low-level wastes, what is the relative importance of environmental barriers such as geological strata versus engineered controls such as containers? Are there any tradeoffs?
2. Should each disposal site have a capacity rating for radioactivity which should not be exceeded?

3. Are the relative advantages of the geology of drier regions great enough to support the tradeoff between the reduced risk at such sites versus the increased risks and costs associated with the transportation of wastes to such regions?
4. What mechanisms are required to prevent site disturbances that may produce environmental impacts?

Control of Radiological Impact to the Population

1. What controls should be implemented on the use of low-level waste disposal sites for purposes other than those for which they were planned? Is it feasible to prevent relocation or use of such sites? Is this of major concern? For how long?
2. Should radon exhalation from low-level natural disposal sites be controlled, and if so, how?
3. What is the objective of low-level and intermediate-level waste disposal: "As low as feasible?" "As low as practicable?" "Below harmful levels?" "Zero planned release?" etc. Are there inconsistencies among such objectives applied to these wastes?
4. Does segregation of wastes by half-life, activity, and/or other characteristics provide a net advantage?

Long-Term Considerations

1. For what length of time should isolation be assured for surface burial of radioactive waste? Should institutions be relied upon to maintain the integrity of sites during this period?
2. Is there a technologically acceptable basis for the retrievability of low-level and intermediate-level waste? Are environmental accidents of major concern? What kind? For how long a time period?
3. In what manner should a site be decommissioned and for how long should surveillance be provided after its operation is terminated?
4. Should the availability of remedial measures in the event of an accident be preplanned, or, because of the nature of the waste and uncertainty of institutional stability in the future, should this approach be avoided?

TOPIC 2 GLOSSARY

Decommissioning - Preparation of worn out or obsolete nuclear facilities for retirement. Decommission operations remove facilities such as reprocessing plants and burial grounds from service and reduce or stabilize radioactive contamination.

Disposal - The isolation of radioactive waste in a manner that precludes recovery, or its placement in a manner that involves natural barriers and is considered permanent so that recovery is not provided for.

Exhumation - The removal of wastes from disposal sites after the site has been filled, closed, and inactivated.

Engineered Barrier - Any medium of containment of human manufacture, such as containers or solidification matrices, which stops or significantly retards the movement of radionuclides to the surrounding environment.

Environmental Barrier - Any medium of containment, either natural or engineered, which stops or significantly retards the movement of emplaced radioactive materials to the environment.

Intermediate-Level Waste - Waste requiring some kind of action to protect personnel from radiation (excluding high-level waste).

Isolation - The location of radioactive waste in such a place that further contact between it and the human environment is highly unlikely.

Long-Lived Nuclides - Radioactive isotopes with half-lives greater than about 30 years.

Low-Level Waste - Wastes containing types and concentrations of radioactivity that do not require shielding to prevent personnel exposure.

Low-Level Naturally Occurring Waste - Those wastes resulting from human activity that contain radioactive materials naturally present in the earth's crust. Significantly elevated concentrations of these naturally occurring radionuclides, such as are found in certain mining and milling residues, have been found to have the potential for radiation exposure to the public.

Natural Barrier - Geologic media exhibiting physical properties that inhibit the dispersion of radioactive wastes.

Radiotoxicity - The property of a material by which it is capable of adversely affecting biological organisms through the mechanism of nuclear radiation.

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Repository - A facility for the storage or disposal of radioactive waste.

Retrievability - A designed capability to remove waste from its place in storage.

Segregation - A method for separating radioactive wastes into different types or classes; e.g., removing all transuranics from the low-level wastes, separating wastes by half-lives, etc.

Shallow Land Burial - The emplacement of wastes in the earth's crust, usually within 50 ft of the surface.

Short-Lived Nuclides - Radioactive isotopes with half-lives no greater than about 30 years, e.g., cesium-137 and strontium-90.

Stablization - The stabilization of tailings piles normally involves grading the tailings area to lessen side slopes, establishing drainage diversion, covering the area with nonradioactive material, and, if necessary, revegetating it. The overall objective of the stabilization process is to minimize erosion and long-term leaching to ground or subsurface waters, and to prevent the tailings from being blown off the site by wind.

Tailings - The portion of an ore remaining after a mineral has been extracted.

Transuranic Elements - Elements with an atomic number greater than 92. They include neptunium, plutonium, americium, and curium.

Transuranic Waste - Wastes known or assumed to contain more than a specified concentration of transuranic elements (presently 10 nanocuries of alpha emitters per gram of waste).

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COMMERCIAL RADIOACTIVE WASTE DISPOSAL: MARRIAGE OR DIVORCE

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Danger--Radioactive waste! How many in the audience viewed that pseudodocumentary which the National Broadcasting Company (NBC) foisted on television viewers on 26 January of this year? I use the term pseudo since the program was a sham in the sense that it presented those portions of a very extensive survey effort which were directed at a single blatant plan by the writer, director, and producer to instill in the mind of the viewer that we have a horrible radioactive waste monster which is about to devour our society!

Let's take a look at one specific issue--an issue that was intended to scare the hell out of every dairy farmer in the United States. A herd of cattle grazing on a farm near the Maxey Flats, Kentucky, burial facility drank water from a small stream which flows away from the disposal site and through the grazing area. At some point in time these cattle became ill and the NBC program all but concluded that the poisoning of the cattle was attributable to radioactive material or a "milky" substance in the stream. A check with D. Robert Singer, Veterinarian with the State of Kentucky Animal Disease Diagnostic Laboratory revealed that the cattle forage was low in copper and phosphorus and was relatively high in molybdenum. The copper-phosphorus deficiency is compounded by the fact that molybdenum inhibits the cattle's uptake of phosphorus. All of the foregoing was explained by Dr. Singer to the writer-producer and the NBC people but they chose not to use the interview with Dr. Singer in their "documentary." Furthermore, the "milky" substance in the poison-producing stream was merely clay which had been eroded into the stream by the earthmoving activities of another farmer immediately upstream of the effected dairy herd. This condition was also fully explained to the NBC crew and the writer-producer. Dr. Singer reported that the diet of the cattle has been supplemented as appropriate and there has been a 100 percent improvement in the herd.

I could go in considerable detail and cite other portions of the program which purported to represent "documented facts" but were selected, winnowed, and sifted with the predetermined position that we must end up with a program which will scare the viewer.

My purpose in citing the NBC "pseudodocumentary" is to point up the fact that this program was only one of many efforts on the part of the nuclear critics to present so-called factual

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information to the American public with the expressed goal of stopping the use of our nuclear resources for the generation of badly needed electrical energy.

Did you know that the nuclear power facilities in the northeastern United States were the mainstay for reliable electric energy during one of the worst winters in recorded history? Without the nuclear power capabilities the effects in terms of life and death could have been disastrous!

The title of my presentation is, "Commercial Waste Disposal--Marriage or Divorce." You are probably wondering what I am driving at. Let me explain.

On 10 March 1977 the Federal Register, Vol. 42, No. 47 published the Nuclear Regulatory Commission (NRC) Task Force Report on their Review of the Federal/State Program for Regulation of the Commercial Low-Level Radioactive Waste Burial Grounds. The very first conclusion of this report reads, "The Task Force can find no compelling health or safety reason for reassertion of Federal control at this time." As we continue through the report, however, we encounter numerous allegations that suggest that the states are not doing a good job and the NRC should take over almost all of the licensing and regulatory responsibilities.

I liken this to my father-in-law, in this case the NRC, who for some reason be it adultery, desertion, drunkenness, or non-support is endeavoring to have my wife, in this case, the State of South Carolina, sue me for a divorce. My wife and I have been happily married for seven years and we both agree that we want to stay married.

It has been brought to my attention that the NRC feels they have a legal right to reassert control of commercial land burial facilities under the conditions of Section 150.15(5) of Title 10, Code of the Federal Regulations which states,

> Persons in Agreement States are not exempt from the Commission's licensing and regulatory requirements with respect to the following activities: (5) The disposal of such other byproduct, source, or special nuclear material as the Commission determines by regulation or order should, because of the hazards or potential hazards thereof, not be so disposed of without a license from the Commission.

The very first conclusion of the Task Force Report which I quoted a moment ago clearly states that there are no compelling health or safety reasons.

One of the recommendations resulting from conclusion 1 would require NRC licensing, with state participation, of current and new disposal sites. I have been personally involved in the commercial disposal of radioactive wastes since 1958 and have been responsible for licensing activities at both the state and the Federal level. On the basis of this experience, I can state categorically that the licensing and ensuing regulatory programs at the state level are (1) more thorough, (2) less time consuming, (3) more responsive to conditions at hand, and (4) conducive to an intimate and cooperative relationship between the regulatory staff and the licensee. The occasion presents itself, quite frequently at our Barnwell facility wherein we have a need for prompt action on the part of the State of South Carolina staff. Such action on the state's part is always prompt unless, of course, some particular technical matter may require some research and investigation. We are never confronted with inordinate delays which I have experienced in the licensing function at the Federal level. Furthermore, since the South Carolina staff offices are located just 70 miles from the facility they are much more conversant with site activities and able to relate intimately and knowledgeably to the operation of the facility.

Another recommendation from conclusion 1 of the report is that a Federally administered perpetual care program is required. The discussion section of the Task Force report goes into some detail as to what would be required for the long term care of a disposal site if an operator should abandon the site or if the site is filled to capacity. The implications drawn from this discussion would indicate that rather extensive surveillance and monitoring would be required and that major problems may arise which would call for major corrective action. It is suggested that the interest from perpetual care trust funds should generate a total between $50,000 and $250,000 annually to support a long-term surveillance program.

As I see it, a monitoring and surveillance program at a filled disposal site will require a minimum of effort and funds provided, of course, that the former operator of the facility had conducted his burial activities in a professional manner. We at Chem-Nuclear agree with the findings of the Task Force that it is difficult to assess accurately what charge should be levied or what total sums should be accrued to establish a perpetual maintenance fund. Our ongoing environmental monitoring program at our South Carolina facility has been under continual review by our company and the state. Jointly we carry out a program which gives us a clear picture of what is or may be in the process of occurring in and around the burial trenches individually and the site as a whole. As the direct result of recent U.S. Geological Survey Studies at our facility we have discontinued "the monitoring well at the end of each trench" concept and are utilizing a "well cluster" system which is directed to actual, observed ground water movement patterns. This "well cluster" system would enable us to almost immediately detect any levels of radioactivity which may occur.

At the present time our company has deposited with the State of South Carolina a sum in excess of $300,000. With an interest rate of 5 percent this escrow fund is now generating over $15,000 per year. Remember, however, that the South Carolina site is not filled, that Chem-Nuclear has no intention of abandoning the site, that we operate the site in a manner which will reduce the long term care requirements and that we are continuing to deposit funds in the escrow account. As the direct result of the Clemson University study made in 1974 we are depositing sixteen cents in the escrow account for each and every cubic foot of waste buried. I estimate that by the year 1990 the escrow fund will exceed two million dollars providing a minimum annual return of over $100,000 per year, which should be adequate for the long term-care program and would also provide funds for the major corrective actions which the NRC alludes to.

On the basis of the foregoing I do not see an immediate and urgent need for a Federally administered perpetual care program. I do see a need, however, for a joint effort on the part of the states and the NRC to develop standards and criteria for long-term surveillance and for a Federally backed contingency funding program which would provide funds for the major contingency actions that might be required.

Our company is currently involved in the development of a low-level site here in New Mexico not too far from the town of Cimarron. We commenced these efforts over a year ago and are concentrating our efforts in an area near Cimarron because geologists and hydrologists advised us that the location appeared to be almost ideal. Contrary to the Task Force finding we feel that adequate capacity is not available through 1990 and in light of the possible closure or unavailability of certain of the existing sites, there is a need to develop additional sites at this time.

In a report entitled, "The Shallow Land Burial of Low-Level Radioactively Contaminated Wastes," prepared by a Panel on Land Burial for the National Academy of Sciences, the Panel finds, and I quote:

> The Panel is aware of ERDA's policy of not establishing any unnecessary additional land burial site for solid low-level radioactive waste. Because of the anticipated volume of such waste to be produced in the foreseeable future, the Panel believes that this policy should be reconsidered in connection with current and long-term needs of the nuclear industry and in view of all other recommendations of this report and other current developments.

The total licensing effort from start to finish is extremely time consuming. The most significant of these efforts is the geohydrological studies which are required to determine if the site will provide for adequate containment of the wastes and also preclude the migration of radionuclides from the trenches. For our effort in New Mexico we have engaged a staff of experts in various areas and have invested close to a half million dollars in the exhaustive programs for establishing the suitability of the proposed site. We feel that our program could serve as the basis for standards and criteria for site development in other parts of the country.

The Task Force report lists eight alternatives and treatment options for radioactive wastes which should be investigated. Of the eight, only one has any immediate viability, that is, special treament (e.g., volume reduction, solidification, and containerization) at regional processing centers prior to disposal. I would like to point out that our company is taking a hard look in this area so that we may extend the useful life of our disposal site. Among the other options are:

1. Disposal in the ocean--the NRC will not license such a disposal method (See Section 20.302 (c) of 10 CFR 20) unless the applicant shows that sea disposal offers less harm to man or the environment than other practical alternative methods of disposal.
2. Retrievable engineered storage--what better way is there for considering retrievability than to place materials in shallow trenches?
3. Disposal at the generation site (e.g., nuclear parks)--this is in direct conflict with the NRC's non-proliferation policy!

The remaining options, while being attractive from the standpoint of isolation from the biosphere, would add tremendously to nuclear power costs and do not present any better scientific arguments than those for shallow land burial.

Finally, the Task Force Report concludes that "the underlying issue of this report is whether the NRC should exercise exclusive licensing and regulatory authority over commercial low-level waste management, or whether this authority should be shared with the states. I can see no compelling evidence to justify an NRC reassertion of exclusive licensing and regulation nor the sharing of such responsibility with the states. As I have stated earlier in my presentation, all of the states are carrying out their responsibilities as set forth in Section 274 of the Atomic Energy Act--in fact in most instances they are, in my opinion, doing a better job.

I would like to quote the following paragraph from the NRC Task Force Report:

The NRC regularly reviews the Agreement State Programs and has found their licensing and regulatory activities to be adequate to protect the public health and safety and compatible with the NRC regulatory program. The reviews include an independent assessment of licensing, inspection and monitoring activities involving the burial grounds. In addition, the NRC has conducted some special studies and investigations at the sites. For example, the NRC has conducted an independent assessment of the Maxey Flats sites, participated in assessment of pilferage at the Nevada site, conducted precautionary inspections to check for further evidence of pilferage and has collected and analyzed independent environmental samples at all sites. In reviewing information about these routine reviews and special studies the Task Force found no evidence that the public health and safety is not being adequately protected.

There are no grounds for a divorce.

A STATE'S VIEWPOINT ON RADIOACTIVE WASTE CRITERIA

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Some of the terms in the title of this session suggest the urgent need for criteria with reference to the disposal of radioactive wastes. The title may imply that there is a well-defined, well-understood distinction between low-level and intermediate-level radioactive wastes. One definition for these terms is:

> Low-Level Waste--Waste containing types and concentrations of radioactivity such that shielding to prevent personnel exposure is not necessary.
> Intermediate-Level Wastes--Waste requiring some kind of action to protect personnel from radiation.

Neither of these definitions is acceptable to me. This approach defines radioactive wastes with respect to the protection of personnel, without considering potential long-range environmental impacts. A given radionuclide may present diametrically opposed potentials for radiation exposure, depending on whether we are concerned with short-term occupational exposure or the potential long-term exposure of populations resulting from environmental release. For example, certain material may require a considerable amount of shielding (due to gamma emitters) to protect personnel, and yet represent no potential for release to the environment because it is in a nonleachable chemical or physical form. On the other hand, waste which primarily contains alpha and beta emitters, for example, strontium-90, may require little or no shielding for personnel protection, while representing a great potential for population exposure and environmental impact if released. The need for adequate and acceptable definitions of waste simply underlines the problem facing us as we seek to develop understandable and adequate criteria for waste disposal.

Since my experience has been restricted to shallow-land or near-surface disposal, my remarks are not intended to apply to surface disposal, such as mine tailings. It is possible, however, that criteria for the one may be applicable to the other.

In Reston, Virginia, several commented that cost-benefit analyses should be applied in the development of any criteria, as well as the important risk benefit analyses. Both are critical as the first steps are taken toward realistic criteria for waste disposal. For example, just how much are we willing to pay for the reduction of one rem of radiation? Or more specifically, what is the maximum we are willing to pay for the reduction of one cancer risk per population? Some would immediately respond that "waste disposal should present no risks to present or future generations, whatever the costs." Assuming that such a philosophy is reasonable, "zero risk" can only be assured by completely stopping the use of radiation-producing materials (and I might add, radiation-producing machines). However, such action is not itself "risk-free," but requires the loss to society of various techniques in the diagnosis and treatment of disease which use radioactive materials, the loss of safety which would attend the stopping of critical nondestructive testing of building materials, etc. Furthermore, consistency would demand the application of this philosophy to the use of other hazardous materials by our society. For example, the use of pesticides presents recognized risks, both to present and future generations. We can be assured of "zero risk" by simply not using pesticides. However, such action similarly creates new, and perhaps greater risks to society in the form of significant losses of crops, resulting in loss of income to farmers and, more importantly, inadequate supplies of food. Certainly our risk-benefit and cost-benefit analyses must reflect the predictable risks and costs which would result from slowing or stopping the use of a resource such as radiation.

The question has been raised whether or not the developed standards should be generic in nature, providing "umbrella-type" coverage for all types of wastes. I believe there are some standards which can be applied to all radwastes. Specifically, I believe there should be a base numerical value for population and individual exposure from the handling, storage, and burial of radioactive wastes. This numerical value must be based on the actual biological risk associated with that exposure. It appears to me that such a baseline numerical value must be established early in the development of suitable criteria or it would be impossible to make cost-benefit or risk-benefit analyses. It is extremely difficult, if not impossible, to apply any analysis to a moving target.

I know that there are those in the audience who see the establishment of a fixed numerical value as a hindrance of the concepts of as low as practicable" or "as low as reasonably achievable." While I fully support these concepts, I must also recognize that the use of these concepts alone leaves us, as regulators, "with our feet firmly planted in the air." These concepts alone provide no fulcrum for any sort of regulatory responsibility and control. Therefore, while every effort should be made to keep exposure as far below this established value as can practicably be achieved, such a value must nevertheless be established as a point of legal reference. Based on a predetermined, accepted biological risk to society, such a value can be applied to all radioactive wastes, whether high-level, low-level or intermediate-level by almost any definition.

Aside from this baseline value, I see few, if any, other standards relating to radwastes which can be applied generically. With reference to the containment of radwaste, for example, discussion has centered on whether natural geologic formations or engineered containment is most important. It would appear, especially in humid regions, that both have a proper role. Depending on the chemical and physical form of the waste, specifically with respect to the leachability and rate of radiological decay, natural geological formations may be adequate for containment. However, this kind of categorization will require a better system of accounting and description of the chemical and physical characteristics of the waste. For example, one type of waste is identified simply as "mixed fission products." This term can apply to more than one type of waste. It may describe waste coming directly from the fissioning process in a reactor, in which case the half-life is calculable. On the other hand, "mixed fission products" is also used to describe a combination of various fission products which have been used individually in medical and industrial facilities. Waste of this kind is a potpourri for which calculation of half-life is impossible.

I would like to add a point here about the relative value of dry versus humid regions for the burial of radwaste. While at present only those shallow land sites in humid regions have encountered problems, one should not assume that sites in drier regions are necessarily the best solution. From the standpoint of cost, a site in a dry geologic formation must be preferred to a site in a humid region, which requires engineered containment. While generally a dry region may be more desirable, we must be sure that there is no long-run potential for water ever reaching a currently dry site.

It appears that I am only raising more questions which must be addressed in the development of a standard. Since I was specifically asked to express my opinion on areas or problems in the development of criteria, I will narrow my focus in the last part of this paper.

One of the problem areas which will have to be addressed relates to the problem of locating shallow land burial sites. The development of siting criteria will open discussion with reference to the relative roles, rights, and responsibilities of states versus the Federal government. Clearly a state will have an entirely different perspective of cost-benefit than would a Federal agency. The state out of necessity defines benefits and costs in relation to the citizens of that state. Experience shows that shallow land burial sites generally provide regional and national benefits, and only indirectly benefit the state. It is my opinion that only in a state with several nuclear facilities would direct state benefits be recognized. Therefore, any siting criteria which are developed must consider and balance risk-benefit and cost-benefit analyses from state, regional, and national perspectives.

For example, regionalization appears to be a necessity from the national point of view since more varied types of geological formations are available. But should one state have to bear alone the costs of perpetual care and monitoring of a site which provides primarily regional and national service? I believe that if regionalization is pursued, then Federal ownership and joint Federal/state regulation of such sites should be implemented. This will effectively balance state and Federal interests and concerns.

From my experience with shallow land burial sites, I offer the following recommendations for consideration:

1. Waste should be segregated in the following manner:
    a. All treated waste (e.g., solidified or ion exchange resins), high-specific-activity waste, and long half-life wastes.
    b. All low-specific-activity waste. Low-specific-activity waste is generally high in organic material content which can result in the complexing of radioactive ions into a soluble and more mobile form. In practice, about 90-95 percent of the volume of waste is low specific activity. This scheme of segregation would then allow the burial of the first category in such a way as to allow for future retrieval.
2. Categorization should not be based on external exposure rates, except for personnel exposure during transportation and handling of the waste at the site.
3. While all shallow land burial sites are only utilized for the disposal of solid wastes, there is no clear definition of "solid." An acceptable definition of "solid," particularly for solidified liquids, is needed. I recommend that any related standard be based on the leaching rate of the material when in contact with water.
4. Each site should have preplanned corrective actions which can be implemented if either geological or engineered containment is breached.
5. There is a need for the development of uniform criteria in the area of bonding and perpetual care of burial sites. National guidance would be beneficial in this area. I recommend that any perpetual care program be based on the biological hazards associated with the waste, and not on some arbitrary unit such as cubic feet or pounds of waste.
6. National criteria should be developed to assure adequate environmental monitoring programs for shallow land burial sites.

I would like to address one other problem. Some have suggested the generic application of these new standards and criteria to all sites, whether proposed or presently in operation. To avoid problems, we must realize waste management concepts, philosophies, and technologies have changed significantly since most of the present shallow land burial sites came into existence. Most of the disposal sites have based their regulatory control activities on the recommendations of the National Council on Radiation Protection and Measurement (NRCP) pertaining to radiation exposure and concentrations of radioactivity. The application of new standards which are significantly different from these established guides will present great problems to existing regulatory programs. I recommend that any criteria developed that are significantly different than these current guidelines not be immediately applied to existing sites. Some reasonable amount of time should be allowed during which the needed changes can be made.

As a representative of a state with an existing shallow land burial site for radioactive wastes, I commend and support the efforts being made by the Environmental Protection Agency (EPA) towards the development of criteria and standards for the disposal of radioactive waste. There is an urgent need for such recommended standards at the national level in order to assure uniformity of management, maintenance, monitoring, and perpetual care of such sites throughout the country. Since many other Federal agencies have responsibilities with respect to matters of radiation health and safety (e.g., the Nuclear Regulatory Commission [NRC], the Energy Research and Development Administration [ERDA], the United States Department of Transportation [U.S. DOT], the Food and Drug Administration [FDA], and the Department of Labor) I strongly urge the EPA to solicit the participation of these agencies in a cooperative development of standards. Furthermore, the Conference of Radiation Control Program Directors, the representative of all state radiation control programs throughout the country, should work closely with these various Federal agencies as an advocate for the state's perspective in this important effort.

Thank you very much for the opportunity to express my views on this timely and important subject.

POLICY CONSIDERATIONS OF LOW-LEVEL AND INTERMEDIATE-LEVEL RADIOACTIVE WASTES FROM A PUBLIC INTEREST PERSPECTIVE

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It is a pleasure to be here to be able to express some of the perspectives and concerns of one of New Mexico's public interest groups. At the outset, I should state that the Central Clearing House is a critic of nuclear power. Many of our criticisms arise from concerns outside the scope of this conference, such as energy needs, uses and abuses, civil liberties issues, etc., but many are germane to waste disposal.

While we understand that it is necessary, in terms of fulfilling the Environmental Protection Agency's (EPA) mandate to develop standards and criteria for waste disposal, to discuss the end of the fuel cycle separate from the entire fuel cycle, somewhat as a physician might diagnose, prescribe, and treat an unhealthy part of the body, it is well for us, and the physician, to keep in mind, at all times, the relationship and interdependence between the two.

One of our concerns, and criticisms, stems from what we feel is a compulsion, sometimes bordering on a fetish, to describe and discuss waste management in a "technical fix" framework. Or, as expressed by Dr. Dean Abrahamson:

> ...the self-interest of the innovator inevitably results in a promotional bias in which the technological benefits are regarded with an indelicate optimism, and detriments as the hobgoblins of small minds. The widespread belief that secondary effects are generally benign, and certainly reversible, is a dangerous complement of the above and is precariously close to violating the second law of thermodynamics. There is in addition the almost holy reverence to the expectation that whatever the problems posed by a technology there is a technical fix (Ref. 1).

It is indeed refreshing that some of the policy decisions underlying "technical fixes" have been recognized by this Workshop.

I emphasize our belief that most of the decisions to be made revolve around non-technical issues. But the majority of the public still suffers from a technological inferiority complex, believing all the substantive problems are technical in nature and therefore, amenable to a "technical fix." This inferiority complex is all too often promoted and encouraged by the makers of the golden calf of technocracy and its disciples.

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We've all been exposed to the doctrine in one form or other--the basic tenet is that only nuclear physicists or chemists or related disciples are qualified to participate in recommendations to the policy makers. The opinions of social scientists, economists, civil libertarians, land use planners, environmentalists, and just plain "at risk" citizens aren't somehow real or valid.

I should like to outline one environmentalist's overview or perspective for your consideration as a suggested framework in discussing waste disposal problems. What is needed is:

1. To define the problem, and it is not clear to me that we've really done that yet. And, at the risk of venturing briefly outside our topic, perhaps we can't fully, until more basic policy regarding the fuel cycle is in effect, i.e., how much of what kinds of wastes will be produced for what periods of time requiring what range of private and governmental resources, as well as natural, economic and institutional resources? More simply stated, waste disposal policies would likely be very different if a decision were to be made to stop generating, or to reduce the generation of, both military and commercial waste;
2. To initially define the solutions to the problem from as idealistic an approach as possible (if I were King sort of thing; the best, if you please, ignoring for the moment costs and conflicts);
3. To define other social goals and values, such as the relative health of our people; the risks we're willing to take with cancer rate increases; the amount of capital we wish, or can afford, to invest in any given energy source; our standard of living, (and parenthetically, I hope that will be measured in such terms as educational opportunities, health care, full employment and clean and healthy home, work and natural environments, etc.), environmental values--in other words, the measure of our value system as a people--not just, and only, the measure of the things we produce and consume;
4. To analyze how other social goals and values conflict with an ideal approach. For instance, we want cheap energy but also want all technically possible safeguards; we want ever-expanding industrial growth, but wish to reduce carcinogens in our environment, etc.;
5. To quantify the risk-benefits of those conflicts;
6. To project various scenarios which reflect differing degrees of compromise, or trade-offs, between other goals and an idealistic approach; and finally,
7. To describe the costs of differing scenarios, including those intangible costs which do not readily, if ever, lend themselves to being quantified in economic terms (cultural and religious values, ethical con-

cerns of a radioactive legacy to future generations, diminution or loss of civil liberties, aesthetics, etc.).

Within this framework, let us explore some of New Mexico's experiences with low-level waste, and as we explore, I will suggest other policy issues and data needs which the working groups may wish to address.

At least one application will be submitted to our state for a low-level commercial radioactive waste disposal site. The NRC has recommended, based on experiences with other states, that no new licenses be issued until standards and criteria are developed. Virtually all independent studies have recognized the inadequacy of the present land burial disposal system. A typical comment, from the Committee on Geologic Aspects of Radioactive Waste Disposal, Division of Earth Science, National Academy of Sciences-National Research Council states:

> The Committee thinks that the current practices of disposing of...all manner of solid wastes directly into the ground above or in the freshwater zones, although momentarily safe, will lead in the long run to a serious fouling of man's environment. Such methods represent a concept of easy disposal that has had and will continue to have great appeal to operators, but we fear that continuation of the practices eventually will create hazards that will be extremely difficult and expensive to eliminate. Although the ion-exchange capabilities of natural earth materials under disposal sites will retain quantities of radionuclides and provide a safe container for the shorter-lived ones, it would appear to be prudent to reserve a large portion of the capacity for accidental releases....The ion-exchange equilibria are reversible, and under changing conditions desorption could replace adsorption. Such a changed situation might result from man's future activities which would affect the hydrologic systems in the aquifers as dams are built, irrigation is accelerated or extended into new areas, or groundwater aquifers are subjected to higher withdrawal rates, all of which are not only possible but likely happenings in forthcoming decades. Climatic changes in future centuries may also be sufficient to alter substantially the hydrology in an aquifer and thereby affect its sorption capacity (Ref. 2).

Several policy questions rise from the almost universal criticism by independent study groups and regulatory agencies:

1. Should states continue to license low-level waste sites, given concerns that they cannot match and apply the same resources to evaluating an application for a commercial site, or should the Nuclear Regulatory Commission (NRC) revoke this authority for agreement states?

2. To what degree should site selection be responsive to state and/or local land use planning or zoning?
3. Without either input or the authority to respond to problems, state and local governments could be placed in the position of being unable to meet their responsibilities. For instance, the Energy Research and Development Administration (ERDA) recently announced its intention to give veto power over disposal sites to the Governor of Michigan. Is this a policy which will be offered to all states? It seems apparent that only the Federal Government has the full range of resources necessary to respond to waste disposal issues and problems. How, then, is this necessity reconciled with the mandates of state and local governments to promote protection for the welfare of their citizenry?
4. Should site selection be limited to land that is either commercially available or governmentally owned, considering, of course, other criteria such as hydrology and geology?

Additional data needs for both commercial sites and uranium mill tailings are clear:

1. A detailed comprehensive assessment of the hazards posed by radionuclides contained in low-level wastes;
2. An analysis of specific land burial methods and procedures;
3. Independent study, evaluation, and rating of the geology, hydrology, and other environmental factors of burial site areas on a national basis, in much the same way as has been attempted with high-level wastes;
4. A risk-benefit study of land disposal of radioactive wastes, which would include a broadly based examination of the environmental risk posed by low-level waste disposal, and a thorough analysis of all possible alternative means of safely disposing of these wastes, with detailed evaluations of the environmental and economic consequences of each alternative;
5. The amount of low-level waste to be produced under different degrees of nuclear development during the next 50 years;
6. An evaluation of the ability of existing disposal sites to retain existing wastes;
7. An evaluation of the safety of existing sites; and
8. An evaluation of costs and resources necessary to remedy known problems at existing commercial sites.

A final overriding concern which encompasses both policy and lack of data in regard to both low-level waste site licensing and licensing of uranium mills by agreement states is the lack of preparaton of environmental impact statements (EIS) prior to granting licenses. The information required of an applicant in either situation is not as complete as that required by an EIS. Under the impact statement process, the regulatory agency is the entity responsible for developing the required information. The agency may, of course, use information supplied by an applicant, but the burden of responsibility for accuracy of information falls on the agency. In an application procedure, not only is the required information not as comprehensive, but it is also the applicant's information which will surely not place him in a bad light. Opportunities for citizen comment and criticism is another important function of the impact statement process. Licensing procedures do not provide comparable opportunities.

In addition to the absence of the impact statement process in agreement states for uranium mills, there are other major and profound policy and data deficiencies. The most obvious, basic, and urgent is jurisdictional responsibility for tailings. This issue is critical. The absence of clear and uniform policy creates an atmosphere for mischief-making by less than socially responsible uranium companies. I'll illustrate this with a gothic tale from the recent New Mexico legislative session. A bill was almost passed which would have allowed mining companies to retain ownership of tailings piles while placing the legal and financial responsibility for the hazards and maintenance of those piles with state government--in effect saying, "If anyone or anything is harmed by the radiation from these piles, the state will pay; but, if we (the industry) should ever find it economical to retrieve some of the goodies from the piles, we can...In the meantime, we want you to spend your money taking care of them for us." It was by the sheerest luck that this bill is not now state law.

Within the jurisdictional policy issue is the issue of adequate fees to cover the costs of defining the radiation hazards, studying and testing various disposal methodologies, and final disposal costs.

As a final recommendation, plea actually, development of definitions for high-level, intermediate-level, and low-level radioactive waste, which will be universally used by all bureaucracies and industry, is needed. Despite what some technocrats might like to believe, we non-technicians are quite capable of understanding a given set of definitions. We do run into difficulty, however, in attempting a dialogue using definitions which change depending on the circumstance.

Thank you again for this opportunity. I look forward to amplifying on these issues during our working group discussion.

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RADWASTE RADIUM-RADON RISK

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The title of this Workshop includes the phrase "policy and technical issues"; the announcement also stated that "invited speakers will provide their opinions on key issues." Consequently, I intend to do what is rarely done by scientists in technical meetings, and that is to state some personal opinions, unsupported by experimental data. After a few brief remarks that can be categorized as "opinions" on "policy," I will devote the remainder of my presentation to "technical issues."

OPINIONS

WHO IS THE "PUBLIC"? WHAT DO WE MEAN BY "PUBLIC PARTICIPATION"?

The public consists of those individuals who make automobiles as well as those who drive them, those individuals who produce electrical power as well as those who consume it, smokers as well as non-smokers, those individuals who mine coal as well as those who mine uranium. Individuals who have developed environmental awareness and have joined environmental groups during the past few years have no more right to claim to represent the public than do the professionals in environmental or health sciences who have been trained and have been working in these areas during their entire professional careers. Opponents of nuclear power have no more claim to being called the public than do the proponents of energy independence.

In a representative form of government we expect our elected representatives to examine issues and take actions on the basis of producing the most good for the most people without infringing upon the rights of any individual. While the realities of the political world do not approach this hypothetical utopia, the results are probably still better than would be obtained if we simply allowed the rules to be made by those individuals who can shout the loudest.

WHAT CONSTITUTES "ACCEPTABLE RISK"?

"Risk" refers to the possibility or the probability of loss, damage, or injury. "Cost" refers to total expenditure of money, labor, time, etc., required to obtain an object or attain a goal; it may also refer to the loss or detriment resulting from failure to achieve the objective. Thus, as a general concept, we can equate "risk" and "cost." Con-

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sequently, there is no sense to try to attain "zero risk at any cost"; that is a conceptual contradiction!

"Acceptable risk" can be defined only with reference to the reason for taking the risk. A risk becomes acceptable at the level at which it reduces a competing risk by an equal amount. The reduction of a competing risk is usually referred to as a benefit, and the methodology for determining the optimum levels of multiple, competing risks is commonly called "risk-benefit analysis" or "cost-benefit analysis." However, a more realistic term for the process might be "cost minimization analysis," since the ultimate objective is to determine optimum levels of competing costs (risks) such that the total cost (risk) is minimized. The obvious difficulty is in the measurement of all types of costs and risks in common units.

In the field of radiation protection we make two fundamental assumptions that permit us to compare the detrimental costs (risks) of radiation doses with the expenditures required to avoid radiation doses:

1. Every increment of radiation dose represents the same cost (risk) regardless of when, where, how, and to whom delivered. This is simply another way of stating the linear nonthreshold model for the biological effects of radiation.
2. The cost of a detrimental health effect is the same regardless of its cause.

The total expenditure we (as individuals or as a society) are willing to make to prevent and/or cure a particular injury or illness, divided by the total radiation dose that would cause the same injury or illness, is the cost per unit radiation dose. The radiation dose required to produce specific illnesses have been expressed statistically as "risk" (Ref. 2).

Many analyses have been made to determine the cost per unit dose, and values ranging from $10 to $1,000 per man-rem have been proposed. Until the data base and methodology for such analyses are improved, most prudent analysts will continue to use the highest cost value, i.e., $1,000/man-rem (e.g., 10CFR50, Appendix I).

WHAT DO WE OWE TO FUTURE GENERATIONS? HOW DOES OUR OBLIGATION TO THE FUTURE CHANGE WITH TIME?

We did not ask to be here, either as individuals or as a society; our parents made that decision for us and we make it for the next generation. Each generation has a high degree of responsibility for the very next generation, but rapidly decreasing responsibilities to generations beyond the next one. If we would simply follow the golden rule with respect to the next few generations, I believe we would adequately satisfy our moral and ethical obligations to the future.

If we have a moral obligation to reduce risks to future generations, that must include risks of all kinds. Suppose, for example, that we were to consider our obligations to the future to decrease by one half for each generation into the future (i.e., the half-life of our future obligations is 30 years). Suppose also that preservation of natural resources was considered to be a proportionate part of our obligation to the future. We might then say that the risk of depletion of any known resource should not increase by more than a factor of two for each future generation. Alternatively, the rate of consumption of known reserves of any resource should not exceed one half per 30 years or 2.3 percent per year. Obviously, if we followed comparable logic for all resources, we would not be consuming our known reserves of oil and natural gas at the present rates.

The argument is sometimes made that we must protect future generations against risks that they may not be qualified to handle on their own. I believe future generations will be just as competent to deal with radioactivity as they are to develop more sophisticated sources of energy. Our obligations to protect them are no greater in the area of radioactive wastes than they are in all areas of resource depletion.

None of the risks we are considering with respect to radioactive waste disposal is likely to appear suddenly. Any adverse effects, such as releases of radioactive materials from waste repositories, if they were to occur at all, would most likely develop over many generations. There would certainly be ample opportunity for future societies to change population distributions or densities if any radiation risk appears to be significantly detrimental and/or uncorrectable.

WHAT CONSTITUTES "LONG-LIVED WASTE"? WHAT IS "LONG-LIVED"? WHAT IS "WASTE"?

As a first approach, three general time scales appear to be logical for categorizing the longevity of toxic wastes or the technologies for their disposal (isolation):

1. Human lifespans and the industrial-technological experience of human society indicate that one appropriate time scale would be in the order of a few decades. Within this time scale there may be some validity to technologic, economic, or sociologic projections. However, even over such relatively short time periods, prognostications for the future are uncertain. Consequently, it seems reasonable to suggest that any plans that are contingent upon projections, or assumptions of socio-economic conditions, more than a few decades into the future should be viewed with skepticism.

2. Political lifespans, i.e., the recorded history of civilizations and political entities, represents a second possible time scale. This time scale would be in the order of centuries to millenia. The historical evidence is quite clear, however, that the preservation of materials or structures from past civilizations has been in spite of, not because of, political activities. Religion and nature have been the two predominant influences in preservation, but even these have not made the monuments of past civilizations inviolate. Any proposal which is dependent upon political stability for many centuries should also be considered highly questionable.

3. Geologic time is the third scale that is available for consideration, and is generally in the order of millions of years. Projections on this time scale are based only on natural forces and not on social or technological assumptions. Even though the time scale is much longer, the extrapolations of probable events are generally more valid simply because natural forces behave more predictably than do humans.

In view of the uncertainties of predictions and the orders of magnitude of time involved, the distinctions between the first two categories are not sufficient to be significant for planning purposes.

If the preceding premises are accepted, all toxic wastes should be placed into only two categories: those that will be degraded to non-toxic substances within a few decades and those that will still be toxic after a few decades (i.e., beyond our own lifetimes). These two categories, and potential disposal methods, would then be:

1. Degradable, or temporarily toxic, wastes, including biodegradable materials, short-lived radioactive materials, etc. Such wastes could be placed in controlled depositories (e.g., engineered storage, restricted shallow burial sites, etc.). Record-keeping and/or monitoring may be required. However, complete detoxification or retrieval should be accomplished within one generation (e.g., 30-50 years maximum).

2. Nondegradable, or permanently toxic, wastes should include all substances that will still be hazardous beyond one generation, even though slow decay rates will occur. Such wastes should be placed in repositories for which containment does not depend on engineered structures but rather on natural stability. Although some investigative monitoring may be desirable during the first decades of use of such repositories, there should be no anticipated

requirement for monitoring for control purposes in the future.

Basic criteria for ultimate repositories should include:

a. The average projected rate of loss from the repository, and the maximum breach of containment from the repository, should result in no more serious consequences during the first few decades of use than are considered "acceptable" to the present generation, i.e., the risk acceptance should not be based on the decay rate of the wastes, but only on the "decay rate" of the repository.

b. If the repository is a geologic formation, it should contain no elements or minerals that are not found abundantly in more accessible locations. This criterion would reduce the risk of future exploration or mining.

WHAT IS "WASTE"? SHOULD WASTES BE RETRIEVABLE?

Retrievability of radioactive wastes has been advocated because of: (1) the possibility of developing better disposal methods in the future, and (2) the possibility that what is "waste" today may have some intrinsic value in the future. Criteria for long-range waste management, to be of any practical utility, must provide guidelines for resolving these uncertainties.

The possibility of developing better disposal methods in the future should be considered in terms of the time scales for "long-lived" wastes discussed previously. Retrievability should be considered for this reason only if there is a substantial probability (not possibility) that a method will be found within this generation that would reduce total risk (before and after emplacement). As long as the methods used by this generation can reduce risks to acceptable levels for the next few generations, there should be no need for future generations to process this generation's wastes.

The possibility that what is waste today may be found valuable in the future can be minimized by subjecting all "wastes" to a complete elemental and mineral compound analysis. No recovery would be anticipated if:

1. All constituents are readily available elsewhere in nature;
2. All constituents are easily produced from raw materials abundant in nature;
3. Any constituent not readily available from natural sources could be produced at an economic cost and health risk less than that required to separate it from the waste; and/or
4. The known hazards or risk from the constituents of the wastes outweigh any known or anticipated benefits.

TECHNICAL CONSIDERATIONS

EXPOSURE PATHWAYS

All radionuclides will produce radiation doses if taken internally and some (those that emit gamma rays and energetic beta particles) produce radiation doses even though outside the body. However, the degree of isolation of radioactive materials from the biosphere that is adequate to prevent intake to the human body will almost always also eliminate the external radiation exposure. On this basis, there is no demonstrated need for subcategorizing low-level radioactive wastes--that is, with one exception. I would like to discuss the exceptional case of radium-contaminated wastes; it is unique because of the production of radon.

RADON EMANATION

In materials containing nuclides preceding radon in the uranium series (i.e., thorium-230 and/or radium-226), it is necessary to consider the mechanisms and consequences of the release of radon.

Under most typical conditions of disposal of such wastes, i.e., burial in a manner that minimizes contact with water and the possibility of leaching, and which also provides sufficient earth cover to reduce gamma exposure rates to essentially the normal background levels, the evolution of radon from the waste becomes the limiting condition of controlling population doses. The rate of radon emanation from a disposal site depends on a number of factors:

1. Concentration of radium in the waste material.
2. Total depth or thickness of the waste material in the disposal site. (The total radon source term is a function of concentration times total volume; however, the effective source term is actually less than the total because of diffusion limitations through the waste matrix and the covering material.)
3. Physical characteristics of the waste material; in particular, particle size, porosity and moisture content are very important in determining the amount of radon that is actually free to migrate and the distance to which it can migrate.

The half-life of radon-222 is 3.82 days, or the mean-life is 5.5 days. Any given activity of the parent, radium-226, will produce an equal activity of radon-222 every 5.5 days. For instance, one curie of radium-226 will produce one curie of radon-222 every 5.5 days, or 66 curies of radon-222 in one year.

Because radon is a noble gas (i.e., monatomic and chemically inert), it may escape from the source matrix by diffusion. However, not all of the radon escapes; some radon atoms may be physically trapped or dissolved even though they are not chemically bound within the particles or grains that contained the radium. The fraction of the radon formed that escapes from the source particles is hereafter designated as E, the escape fraction (it has also been called the "emanating power"). The value of E is in the range of 0-0.20 for many types of rock (Ref. 3). In dry sand tailings from the uranium mill in Grand Junction, Colorado, E was found to be 0.23 ± 0.03 (Ref. 5). In the human skeleton, E varies with time following the deposition of radium, i.e., 0.9 for deposits less than 3 months old to 0.7 for deposits that are many years old (Ref. 16).

The radon that escapes from the particles may migrate through the source matrix by molecular diffusion. The porosity and moisture content of the waste matrix is extremely important in determining the mean diffusion distance or "relaxation length" for radon in the material. The factors that determine the extent of the diffusion are illustrated by the following equation (Ref. 5). It describes the concentration of radon as a function of depth in a porous, homogeneous, slab source.

$$(k/p)\ (d^2C/dx^2) - \lambda C + [Ra]E\rho\lambda/p = 0 \qquad \text{[Equation 1]}$$

where

k = effective diffusion coefficient in the gas phase of the source matrix (cm^2/s)
p = porosity of the source matrix (gas volume divided by total volume)
C = concentration of radon in the gas phase (pCi/cm^3)
x = depth into slab from the surface (cm)
λ = radon decay constant (s^{-1})
$[Ra]$ = radium concentration in the source matrix (pCi/g)
E = escape fraction of radon from the source matrix (also called "emanating power"); fraction of radon formed that escapes the source particles
ρ = density of source matrix (g/cm^3).

If Equation 1 is solved for the net flow (flux) of radon outward from the surface of the slab source, the following equation is obtained:

$$\phi = -k(dC/dx) = [Ra]\rho E\lambda \ell \tanh(X/\ell) \qquad \text{[Equation 2]}$$

where

ϕ = net radon flux (pCi/cm^2-s)
ℓ = $(k/\lambda p)^{1/2}$ = mean diffusion length (cm)
X = depth of source matrix (cm)

For X/ℓ =	1	2	3
$\tanh (X/\ell)$ =	0.76	0.96	0.995

For any depth, X, at least twice the mean diffusion length, ℓ, the radon flux will be the same as if coming from a source of infinite depth, that is:

$$\phi_\infty = [Ra]\rho E\lambda\ell$$

A mean diffusion length, ℓ, of 1.5 m was measured for dry, uncompacted sand tailings from the uranium mill in Grand Junction, Colorado (Ref. 5). Values of ℓ in other media have been estimated to be (Ref. 19):

$\ell \approx$ 0.75 m in packed earth with 10 percent moisture.
$\ell \approx$ 0.05 m in packed montmorillionite clay with 30 percent moisture.
$\ell \approx$ 0.01 m in water.

The value of λ is a constant ($2.1 \times 10^{-6} s^{-1}$) and the density of soil or tailings is typically 1.3 - 1.7 g/cm^3 and does not vary widely. If we assume the maximum values for E(0.25) and ℓ(200 cm), the maximum flux from the surface of a thick, unshielded source slab may be expressed as:

$$\phi_\infty \quad (pCi/cm^2\text{-}s) \approx 1.6 \times 10^{-4} [Ra] (pCi/g) \qquad \text{[Equation 3]}$$

Expressed in other units of surface area and time (Ref. 21):

$$\begin{aligned} \phi_\infty \quad (pCi/m^2\text{-}s) &\approx 1.6[Ra] \\ \phi_\infty \quad (Ci/acre\text{-}yr) &\approx 0.2[Ra] \end{aligned} \qquad \text{[Equation 4]}$$

For a tailings pile containing 500 pCi of radium per gram, the radon release rate could conceivably be as high as 100 Ci per acre per year.

RADON INDOORS

The radon flux entering the atmosphere is the effective source term for determining the radiological impact of uranium or phosphate mill tailings. The total radiological impact is, however, determined not only by the amount of radon released, but by the exposure conditions that exist directly above or near the disposal area. The worst situation would occur if structures had been built over the disposal area. In this case, radon would diffuse into confined spaces and be trapped for periods of time sufficient to allow ingrowth of radon progeny and corresponding inhalation exposures. Only three variables need to be determined in order to predict the average indoor radon concentration in a typical structure built over tailings. These three variables are: (1) the total rate of entry of radon activity into the structure, i.e., the radon flux; (2) the ratio of the surface area through which radon is diffusing to the enclosed volume available for dilution; and (3) the average exchange rate of air in the structure.

The maximum influx of radon occurs if there is no barrier to diffusion between the surface of the soil and the interior of the structure. There are several circumstances that can lead to the effective lack of a barrier: (1) a residence built over a crawl space and with some air exchange between the crawl space and the interior of the home, or (2) a porous and cracked concrete basement floor slab. Under these "worst case" conditions as much as half (0.5) of the radon that diffuses out of the ground under the structure may enter the habitable portion of the structure. To complete the "worst case" situation one might postulate an average air retention time of 2 hours (effective loss rate of 1.4×10^{-4}/sec). If the interior height was only 8 ft (typical new residence ceiling height), the surface to-volume ratio is 1/8 ft, or 1/244 cm. Since the physical decay rate of radon is 2.1×10^{-6}/sec, the effective loss rate will be entirely dependent upon and essentially equal to, the ventilation exchange rate.

For any enclosed rectangular volume of height, h, above a slab source from which radon is emanating, the radon concentration under equilibrium conditions can be expressed as:

$$C_\infty = \phi B \tau / h \qquad \text{[Equation 5]}$$

where

C_∞ = radon concentration in air at equilibrium (pCi/cm^3)
ϕ = radon flux through barrier into structure (pCi/cm^2-s)
B = barrier reduction factor, i.e., fraction of flux at soil surface actually entering structure
τ = mean residence time of air in structure (s)
h = interior height (cm)

In more commonly used units (C_∞ in pCi/liter, ϕ_∞ in pCi/m^{2}s, τ in minutes and h in feet), Equation 5 becomes:

$$C_\infty = 0.2\ \phi_\infty B\ \tau / h \qquad \text{[Equation 6]}$$

An example, using realistic values, may provide perspective to the relationship between indoor radon concentrations and underlying radium contamination.

Assume

R_a = 50 pCi/g
ρ = 1.3 g/cm^3
E = 0.2
ℓ = 0.75 m = 75 cm
B = 0.1

τ = 30 min
h = 8 ft

Then

$$\phi_\infty = (50)(1.3)(0.2)(2.1 \times 10^{-6})(75)$$
$$= 2.0 \times 10^{-3} \text{ pCi/m}^3\text{-s} = 20 \text{ pCi/m}^2\text{-s}$$

And

$$C_\infty = 0.2(20)(0.1)(30)/8$$
$$= 1.5 \text{ pCi/liter}$$

Although the preceding calculation is presented only as an illustration, it is based on reasonable estimates of the many parameters involved. The calculated result can be compared with the normal (background) radon concentration that is expected in the absence of any concentrated radon sources. Examples of normal radon concentrations are:

C(pCi/liter)	Location	Reference
0.2	Outdoors, Hungary	11
3.05	Indoors, Hungarian residences	11
0.2	Outdoors, New York City	12
0.26	Indoors, 5th floor, HASL*	12
6.0	Indoors, basement, HASL*	12

RADON PROGENY AND LUNG DOSE

The significant dose to the human respiratory tract is not delivered by radon directly, but rather by its short-lived decay products. The effective concentration of these short-lived radon progeny is expressed in units of "working levels," or WL. One WL is defined as any combination of short-lived radon progeny (polonium-218, lead-214, bismuth-214 and polonium-214) in one liter of air that will release 1.3×10^5 MeV of alpha particle kinetic energy during decay to lead-210. Cumulative exposures are expressed in working level months (WLM) where one WLM would result from exposure to a concentration of 1 WL for one working month, or 170 hours. For occupational exposure only (40 hours/week), the annual cumulative exposure is 12 times the average exposure concentration in WL, that is:

$$\text{WLM/yr} = 12\ \overline{\text{WL}} \text{ (occupational)}$$

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* Health & Safety Laboratory, ERDA, 376 Hudson St., New York, N.Y.

For continuous, non-occupational exposures (168 hours/week):

$$\text{WLM/yr} = 50\ \overline{\text{WL}}\ \text{(continuous)}$$

The radon progeny are formed in the air as the radon decays; consequently some time is needed for the concentration in WL to develop. This ingrowth process is described in detail by Evans (Ref. 9). The ingrowth of WL from initially pure radon can be described by the following equation:

$$\text{WL} = 0.01\ C(1-e^{-\tau/55}) \qquad \text{[Equation 7]}$$

where

C = radon concentration (pCi/liter)
τ = ingrowth time since radon was free of progeny (min)

For the previous example where $C = 1.5$ pCi/liter and $\tau = 30$ min, WL = 0.006.

The relationship between WLM and lung dose is not well established but is generally assumed to be approximately 0.5 rad/WLM or 5 rem/WLM (Ref. 2). The Environmental Protection Agency (EPA) (Ref. 8) has elected to make direct conversions from radon concentrations to lung doses. On the basis of the assumption of "adequate" indoor ventilation and a depth of 60 μm for critical cells in the bronchial epithelium, the EPA has selected a dose conversion value of 4 mrem/yr resulting from continuous exposure to an average radon concentration of 1 pCi/m^3. This converts to 4 rem/yr from 1 pCi/liter.

For the case of the illustration used earlier, the conversion factor of 5 rem/WLM would indicate an annual average lung dose of:

$$(0.006\ \overline{\text{WL}})(50\ \text{WLM/yr-}\overline{\text{WL}})(5\ \text{rem/WLM}) = 1.5\ \text{rem/yr}$$

Use of the EPA conversion factor would indicate a dose to certain cells of the bronchial epithelium of:

$$(1.5\ \text{pCi/liter})\ \left(\frac{4\ \text{rems/yr}}{\text{pCi/liter}}\right) = 6\ \text{rems/yr}\cdot$$

Even with the uncertainties involved,* it should be apparent that substantial lung doses may result from relatively low radon concentrations.

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* Based on various data and calculations, the author believes that the best average conversion factor for lung dose from radon and progeny in the environment is approximately 1 mrem/yr per pCi Rn/m^3, or 1 pCi/liter continuous radon inhalation will deliver 1 rem/yr to the lungs.

RADIUM-RADON REPOSITORY REQUIREMENTS

Because of the long lives of thorium-230 and radium-226, it is apparent that there can be no dependence upon institutional controls of continued surveillance. It is essential that wastes containing these nuclides be disposed of in final form as soon as possible after the wastes are generated. The physical conditions that lead to exposures also indicate some possibilities that ought to be considered for disposal of such wastes. Since radon emanation is directly proportional to radium concentration, one of first approaches that comes to mind is the reduction of the concentration of radium in the waste material. Removal of a significant fraction of the radium during the uranium extraction process may be feasible. Extraction of the radium would provide an advantage in reducing the hazard from the bulk of the waste material and concentrating the hazard into a small volume that might be disposed of in a manner comparable to that envisioned for high-level radioactive wastes. On the other hand, the radiation doses to workers involved in extraction, packaging, transport and placement of the radium concentrates might negate some of the other benefits. This concept should not be discarded, however, until a thorough evaluation of technical and economic considerations has been performed.

Since the escape fraction of radon from wastes matrices depends upon mineral structure and particle size, it may be feasible to drastically reduce the radon escape by some form of vitrification of uranium mill tailings. If true vitrification is too expensive, simpler alternatives to reduce either the escape fraction, E, or the diffusion length, ℓ, of radon could be considered. For example, the tailings might be mixed with clay, or buried in layers with interspersed layers of clay, etc.

The third, and very obvious, method of control is to bury wastes deeper, since the depth of covering will determine the amount of radon that can reach the surface. Several alternatives for final covering and stabilization of a tailings pile have been considered in the Draft Environmental Statement for the Bear Creek Project (Ref. 19).

Of the tailings management alternatives that were considered to be technologically feasible, the one identified as optimum for use at the Bear Creek Project is the provision of a clay liner under the tailings impoundment and the addition of a clay cap 25 cm thick over the top of the completed tailings pile. A cap of this thickness (of a typical montmorillonite clay with a moisture content of 30 percent) would reduce the radon escape by a factor of approximately 100. For the Bear Creek Project it was estimated that this technology would reduce radon release by approximately 98.6 percent, resulting in an emission rate only 2 times the natural background rate. This would obviate the necessity of long-term monitoring and maintenance, except that measures such as appropriate entries in the land deed must be taken to ensure that the tailings pile will not be disturbed or used for any purpose.

RADIUM REGULATIONS

Several/many/all states (I am not sure how many states should be included) "require" licensing of materials containing radium in concentrations exceeding 0.1 pCi/g of solids. For a naturally occurring radionuclide this concentration is unrealistically low. Even some foods, notably Brazil nuts, as well as most soils, contain radium in concentrations exceeding 0.1 pCi/g (Refs. 7, 10). Many construction materials contain radium in excess of this concentration (Refs. 6, 20, 22).

The need for a lower level of concern, a "de minimus" concentration or quantity of radioactivity, is almost as urgent as the need for criteria for high-level waste disposal. For radium contaminated construction materials, soils, and other nonedible environmental media, the concentration of radium that could be considered "environmentally safe and acceptable" (i.e., an "ESA" concentration or specific activity) depends on the external exposure rate from gamma rays and the inhalation rate of radon progeny that could be attained in a relatively small space surrounded by radium bearing materials. I am quite confident that the proper value (with due regard to dose rates, total doses, quality factors, etc.) is in the range of 4 to 40 pCi/g.

It seems apparent that radium concentrations exceeding 40 pCi/g in construction or fill materials can lead to undesirable dose situations. It is equally clear that radium concentrations of 4 pCi/g ought to be ignored simply because they are not distinguishable from the natural background.

To narrow down the range further requires some detailed research. However, since the logarithmic mean of the range of uncertainty is about 13 pCi/g, and the arithmetic mean is about 22 pCi/g, it appears that an estimate of about 15-20 pCi/g would be appropriate as the lower limit for regulatory control. Before such values are accepted, however, they should be checked experimentally.

BEHAVIOR OF NATURAL RADIOACTIVITY

The most difficult problems of radioactive waste disposal involve only natural radioactivity. The natural radioactivity I am referring to is not in its natural state, at least not in terms of its distribution; it is radioactive material that has been rearranged by the activities of man.

There is nothing mysterious or prejudicial in the statement that wastes containing natural radionuclides represent larger potential disposal problems than the wastes from the nuclear power industry. There are two reasons for this situation: (1) the volume of wastes contaminated with natural radioactivity is so large that it appears to be economically impractical, if not physically impossible, to bury all of these materials at depths sufficient to eliminate the radiation exposures; and (2) the natural radioactivity of concern is primarily the uranium decay series, which contains a highly toxic radionuclide (radium-226) which also decays to a gaseous product (radon-222) that is extremely difficult to contain or control.

The natural radioactivity in waste materials not only creates problems, it also provides information to help solve the problems. There is a substantial similarity between the man-made nuclides (activation and fission products) of concern in the nuclear fuel cycle and the naturally occurring radionuclides that appear not only in the nuclear fuel cycle but in wastes from other sources. The first similarity is that the nuclides of greatest concern in all of these waste categories are bone-seekers (see Table 1). The second similarity is that all of the nuclides of concern are long-lived; strontium-90 was included in Table 1 primarily as an example of a bone-seeking fission product, even though it is not long-lived compared to the other nuclides listed in Table 1.

If one recalls that for every 3.3 half-lives, the activity, and consequently the hazard, decreases by a factor of 10, it is obvious that the relative risk due to strontium-90 will decrease by a factor of 10 every 100 years, i.e., in 200 years the relative risk will be 1 percent of the current risk, in 500 years the risk will be 0.001 percent of the current risk, etc. It should also be noted that the simple relationship of the radioactive decay for single nuclides does not hold true for chains of decaying nuclides; for example, Gera (Ref. 13) has pointed out that the ingrowth of radium-226 in high-level wastes from the nuclear power industry will make the toxicity of radium-226 the limiting nuclide in those high-level wastes after about 50,000 years, i.e., after 25 or 30 half-lives of radium.

The distribution of the natural radionuclides in nature, and the limited extent to which they are transported from locations underground into the biosphere, provides a data base from which to judge the risks produced by geologic disposal of other long-lived radioactive wastes.

A very interesting analysis was performed by Gera (Ref. 13) comparing the environmental behavior of natural radionuclides with the kinds and quantities of radionuclides expected in high-level wastes of the nuclear power industry. He used the LAI (limit of annual intake) per unit volume of waste as a relative hazard index. This is somewhat better than the use of dilution volumes since it accounts for differences in specific activities and concentrations of the waste materials

TABLE 1 BONE-SEEKING RADIONUCLIDES OF INTEREST IN RADIOACTIVE WASTE MANAGEMENT

	Nuclide			
	Carbon-14	Strontium-Yttrium-90	Radium-226 and Progeny	Plutonium-239
Physical half-life (yr)	5,730	29	1,602	24,300
Specific activity (Ci/g)	4.4	140	1	0.062
Production mechanism	activation	fission product	natural uranium series	activation "breeding" n + uranium-238
Oxygen-17	(n,α)			
Nitrogen-14	(n,p)			
Assumed chemical form	CO_2 or $NaHCO_3$	any form occurring in the environment: $3<pH<11$		
Uptake (fraction absorbed following ingestion)	1(c)	0.2-0.3(a)(c)	0.2-0.3(a)(c)	3×10^{-5}(a)(b)(d)(f)
Mean residence time in bone (days)(a)	0.58	980	125	18,000
Integral absorbed dose to bone (rad/μCi ingested)	0.00066	2.0±0.4	2.5±0.5	0.017
Assumed RBE in bone	1	1	10	10
Assumed relative damage factor (DF) in bone	5	5	1	5
Conversion (rem/rad)	5	5	10	50
Dose commitment to bone				
(rem/μCi ingested)(a)	0.00033	10±2	25±5	0.85
(rem/μg ingested)	0.05	1,400±300	25±5	0.05
Risk of bone sarcoma(e)(g)				
(per μCi ingested)	3.5×10^{-8}	5×10^{-5}	1.3×10^{-4}	3.4×10^{-6}
(per μg ingested)	3.5×10^{-7}	7.8×10^{-3}	1.3×10^{-4}	2.1×10^{-7}

(a) Ref. 14.
(b) Ref. 15.
(c) Ref. 16.
(d) Ref. 1.
(e) Ref. 18; 200 bone sarcomas/10^6 person-rad for bone surface seekers; 53 sarcomas/10^6 person-rad for bone volume seekers; RBE (surface α/volume α emitters, or plutonium/radium) = 4.
(f) Ref. 24.
(g) Ref. 2.

involved. One of his conclusions was that a typical unstabilized pile of uranium mill tailings would represent the same hazard potential as a high-level waste repository after 100,000 to 200,000 years of decay.

Some interesting lessons can be learned by observing the actual behavior of materials in nature. For example, the risk of leaching buried radioactive materials and contamination of water supplies can be estimated from the mobilization of uranium and radium in the Colorado River drainage basin. The justification for the calculations rests on two factors:

1. The source materials (uranium and radium) are rather widely distributed and not highly isolated from the surface; thus they probably are more accessible to leaching than would be the materials in any carefully selected waste repository.
2. The source materials have been subjected to the forces of nature, i.e., erosion and leaching, for geologic time periods; thus we can observe the real long-term release rates.

The data upon which the calculations are based were originally general in nature and have been further generalized by interpolation or extrapolation. The scope of this presentation, however, is not to make predictions with a high degree of accuracy, but rather to provide a rational frame of reference for making order-of-magnitude calculations and, particularly, for evaluating "worst case" conditions.

COLORADO RIVER BASIN DATA

General information about the Colorado River--drainage area, flow rates and sediment content--are listed in Table 2. A summary of some of the available data on uranium and radium concentrations in the Colorado River are shown in Table 3. It should be noted that all of the data in Tables 2 and 3 represent time periods of at least 10 years, and that the concentrations in Table 2 include significant contributions from uranium mining and milling operations over the past decade. The fact that radium never appears in equilibrium with uranium in the river water could be due to preferential leaching of uranium, and/or preferential scavenging of the radium by aquatic organisms. Tsivoglou (Ref. 23) reported reconcentration factors of 500-1,000 in aquatic insects and algae.

The normal concentration of radium in the Colorado River is only 6 percent of that which would be in equilibrium with the uranium concentration. Just downstream from the Moab, Utah, mill, however, the radium concentration increases to 11 percent of equilibrium, indicating an additional contribution from the milling operations.

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TABLE 2 COLORADO RIVER DATA(a)

	Annual average flow rates(b)	
	Acre-feet/Year	Liters/Year
Colorado to Utah (near Cisco, Utah)	4.5×10^6	5.5×10^{12}
Wyoming to Utah (Flaming Gorge)	1.7×10^6	2.1×10^{12}
to Lake Powell, Utah	10.0×10^6	12.0×10^{12}
U.S. to Mexico (Border Station)	8.0×10^6	9.8×10^{12}

(a) From National Weather Service and U.S. Geological Survey offices, Denver Federal Center. All values are averages for 1953-1967.

(b) Drainage area: 225,000 mi^2; sediment content: 3 to 6 percent by volume; 2.3×10^8 tons/yr = 2.1×10^{14} g/yr.

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TABLE 3 NATURAL RADIOACTIVITY IN THE COLORADO RIVER[a]

Location	Uranium (μg/l)			Radium (pCi/l)			Ratio of Averages[b] (μCi Ra/gU)
	Min.	Max.	Avg	Min.	Max.	Avg	
Fruita, Colorado (Colorado to Utah)	3.5	9.87	7.88	0.11	0.22	0.16	0.020
Moab, Utah (downstream from mill)	8.19	12.30	10.32	0.18	0.91	0.37	0.036
Boulder City, Nevada (Lake Mead outflow)	6.40	9.25	7.69	0.10	0.40	0.29	0.038
Border station (U.S. - Mexico)	5.45	8.85	7.32	0.10	0.18	0.15	0.020

(a) Data obtained from the Environmental Protection Agency, Region 8, Denver Colo. All values are annual averages for ten or more years through 1972.

(b) At equilibrium, as in undisturbed ore, the Ra/U ratio is 0.33 μCi Ra/gU.

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Additional general information on uranium and radium concentrations in the environment of the western states is provided in Table 4. It is interesting to note that the radium concentration in sediment is the same as that which would be in equilibrium with 4 ppm of uranium, although this is not interpreted to mean that all of the sediment was derived from rock containing that much uranium. More likely, the high radium content of the sediment is the result of the reconcentration by algae. The water concentrations listed in Table 4 are general for the western states, and include water supplies derived from snowmelt, underground aquifers, etc., and not merely rivers. The fact that the Colorado River data (Table 3) are in the high concentration range, representative of water sources in the vicinity of uranium mines, is one of the circumstances that makes the analysis which follows somewhat indicative of the "worst case."

URANIUM AND RADIUM SOURCE TERMS

In order to estimate the fractional leaching rates, the total amount of uranium (and radium) contained in the area under investigation must be estimated. The most conservative, though unrealistic, estimate can be made by considering only the uranium that could be economically extracted. Projections of uranium reserves are listed in Table 5. Even though these projections include substantial quantities in addition to those which are "reasonably assured," it is equally obvious that the quantities would be much larger if one were to consider sources that could be extracted at $50 or $100 per pound. These figures, therefore, constitute the very smallest source term for the loss rate calculations and, consequently, produce the largest calculated loss rates.

The other approach to arriving at a source term for purposes of calculations is to assume the typical uranium concentrations in rock (Table 4) and, further, to assume that all of the losses are from a surface layer whose depth can be determined. For the purpose of making the loss rate calculations, I chose to consider a layer 1 km deep since that would include essentially all uranium mines, water wells, and aquifers that recharge the Colorado River.

To obtain a range of loss rate estimates, I selected two portions of the Colorado River drainage area as being representative of "worst case" and "average" conditions. The "worst case" was taken to be the area of intensive mining and milling operations drained by the Colorado, Gunnison, and Dolores rivers, down to Moab, Utah. This drainage area covers approximately 20,000 mi^{2} and there are no very large impoundments along these rivers which would reduce the uranium and radium content by gross sedimentation. In order to assure that this represents the "worst case," the water concentrations used in the loss rate calculations for this area are those obtained just downstream from the uranium mill at Moab.

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TABLE 4 URANIUM AND RADIUM CONCENTRATIONS IN ROCK, SEDIMENT, AND WATER IN THE WESTERN STATES

Environmental Media	Uranium	Radium
	Concentrations in rocks[a]	
Basic igneous:	0.6 ppm	0.2 pCi/g[b]
Intermediate igneous:	1.5 ppm	0.5 pCi/g[b]
Acid igneous:	3.0 ppm	1.0 pCi/g[b]
Granite	4.0 ppm	1.3 pCi/g[b]
Sedimentary	1.2 ppm	0.4 pCi/g[b]
	Concentration in sediment[c]	
	--	1.3 pCi/g (dry)
	Concentrations in water[d]	
Most sources	3 μg/liter	<0.1 pCi/liter
Some sources	--	0.2-0.3 pCi/liter
Near uranium mines	8-10 μg/liter	0.8-1 pCi/liter

(a) Typical values; ref. 17.
(b) Calculated for decay equilibrium with the uranium.
(c) Mean value; ref. 23.
(d) Normal for western U.S.; ref. 23.

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TABLE 5 URANIUM RESERVES IN THE UNITED STATES, U_3O_8 [(a)]

Cost of Extraction	Reasonably Assured (tons)	Estimated Additional (tons)	Total Reserve (tons)
$10/lb	390,000	680,000	1,070,000
$10-15/lb	190,000	360,000	550,000
$15/lb	580,000	1,040,000	1,620,000

(a) From Atomic Energy Commission Press-Release No. O-67, April 30, 1967. Even though these data are ten years old they have not changed so much that updating would change the magnitude of the calculations or the conclusions.

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The "typical" area used for the calculations is that which drains toward Lake Powell, the first major impoundment of the Colorado River. In addition to the Colorado River flow from Moab, major contributions to the Lake Powell inflow are made by the Green River from the north and the San Juan River from the south. The total drainage toward Lake Powell covers approximately 100,000 mi^2 and includes a very large fraction of the U.S. uranium reserves.

The lower Colorado River basin, below Lake Powell, was not used for making loss rate calculations because of the high sedimentation and water extraction rates.

LOSS RATE CALCULATIONS

Three sets of loss rate calculations were made for each of the two drainage areas. A maximum source term was derived by assuming a uranium concentration of 4 ppm in the top 1 km, as if it were composed entirely of granite. A realistic source term was derived from an assumed concentration of 0.1 ppm, representing shale and sedimentary rock in the top 1 km. A minimum source term was derived from an estimate of the economically extractable U_3O_8 in each area. For this purpose, the following assumptions were made regarding the distribution of the uranium reserves (Table 5):

1. Of the 1.6 million tons of U_3O_8 reserves, 50 percent, or 800,000 tons, lies within the entire Colorado River basis (225,000 mi^2).
2. Within the area draining to Lake Powell (100,000 mi^2) there would be approximately 500,000 tons of U_3O_8, or 4×10^{11} gU.
3. The area draining to Moab, Utah (20,000 mi^2) would contain approximately 100,000 tons of U_3O_8, or 8×10^{10} gU.

Since the calculated loss rates are intended only to be order-of-magnitude estimates, the accuracy of the input parameters is not crucial. The loss rate calculations are shown in Table 6. I am of the opinion that the most realistic and valid of the calculated loss rates is that for uranium based on 0.1 ppm in the top 1 km of the drainage area to Lake Powell. This loss rate was calculated to be 2×10^{-6} per year, with other values for uranium ranging from a low of 5×10^{-8}/year to a high of 8×10^{-4}/year. The calculated loss rates for radium were all approximately an order of magnitude lower than those for uranium because of the low radium concentrations observed in river water.

Some of the difference in loss rate, or "underground mobility," between radium and uranium may be accounted for readily on the basis of their sorption characteristics in

TABLE 6 CALCULATED LOSS RATES FOR URANIUM AND RADIUM FROM THE UPPER COLORADO RIVER BASIN(a)

	Drainage to Moab, Utah			Drainage to Lake Powell		
Drainage areas	20,000 mi^2			100,000 mi^2		
Flow rates	6×10^{12} liters/yr			1.2×10^{13} liters/yr		
Sediment transport based on 4.5 percent by volume and density of 1.6 g/cm^3	5×10^{14} (g/yr)			1×10^{15} (g/yr)		
Mass of soil and rock in top km (3,300 ft) of area based on density of 1.6 g/cm^3 (a)	8×10^{19} g			4×10^{20} g		
Assumed uranium content	4 ppm in top km	0.1 ppm in top km	extractable U_3O_8	4 ppm in top km	0.1 ppm in top km	extractable U_3O_8
Quantities in place						
Uranium (g)	4×10^{14}	8×10^{12}	8×10^{10}	2×10^{15}	4×10^{13}	4×10^{11}
Radium (Ci)	1×10^{8}	2×10^{6}	2×10^{4}	6×10^{8}	1×10^{7}	1×10^{5}
Quantities Transported (including mining and milling activities)						
Uranium (g/yr)	6×10^{7}	6×10^{7}	6×10^{7}	9×10^{7}	9×10^{7}	9×10^{7}
Radium (Ci/yr)	2	2	2	4	4	4
Fractional loss rates (all mechanisms)						
Uranium	2×10^{-7}/yr	8×10^{-6}/yr	8×10^{-4}/yr	5×10^{-8}/yr	2×10^{-6}/yr	2×10^{-4}/yr
Radium	2×10^{-8}/yr	1×10^{-6}/yr	1×10^{-4}/yr	7×10^{-9}/yr	4×10^{-7}/yr	4×10^{-5}/yr

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(a) Includes losses from erosion, leaking, mining, and milling.

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soil. Burkholder (Ref. 4) gives the following estimated values for sorption equilibrium constants in western U.S. desert soil:

Element	K^{-1} = nuclide velocity/water velocity
Carbon	1×10^{-1} (50 times K^{-1} for radium)
Strontium	1×1^{-2} (5 times K^{-1} for radium)
Radium	2×10^{-3}
Plutonium	1×10^{-4} (5% of K^{-1} for radium)
Uranium	7×10^{-5} (3.5% of K^{-1} for radium)

The above estimates could be used in combination with the preceding estimates of average underground mobilities to evaluate risks of water contamination from relatively shallow burial of low-level radioactive wastes.

SUMMARY POINTS ON RADIUM-RADON WASTE MANAGEMENT

1. Radium and radon represent the major hazard in several categories of radioactive waste, at least at some point in time. They will be the major hazard at all times in the most voluminous of the low-level wastes, i.e., the mining and milling wastes.
2. Reduction of radon inhalation exposures will be one of the most crucial and expensive objectives in low-level radioactive waste management.
3. Natural environmental radioactivity presents an excellent analogue to other low-level but long-lived wastes for purposes of evaluating risks.
4. There is an urgent need for criteria on quantities or concentrations of radioactivity that may be considered acceptable in the environment. Such criteria should be based on the same types of dose and cost considerations as used to establish environmental criteria for high-level waste disposal.
5. The regulatory limit for radium-bearing materials subject to licensing cannot be reasonably established at 0.1 pCi/g. A concentration of approximately 15-20 pCi/g should probably be the lower limit on concern for nonedible, or nonconsummable, environmental media.

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POLICY AND TECHNICAL CONSIDERATIONS FOR INTERMEDIATE-LEVEL AND LOW-LEVEL RADIOACTIVE WASTE: SUMMARY AND CONCLUSIONS OF WORKING GROUP 2

The topic of Working Group 2 was policy and technical considerations for low-level and intermediate-level radioactive waste. About 70 persons were involved in the first two sessions of the working group. The group included government employees, industry representatives and consultants, public interest groups and citizens representing themselves. The variety of affiliations enabled the group to consider a wide spectrum of viewpoints in their deliberations.

In the first two sessions, procedural problems and definitions were discussed. It was concluded by the end of these initial sessions that the group was too large to function efficiently in view of the short time available and the breadth of the subjects to be covered. Consequently, Working Group 2 broke up into two smaller groups for the second day of the Workshop and the subject matter was divided thusly:

Section A.	Low-level naturally radioactive wastes (mill tailings, phosphate tailings, etc.)
Section B.	Low-level and intermediate-level wastes other than those defined in A.

The division was based primarily on the fact that each of the above groups of radioactive wastes have different characteristics relative to waste management.

The first topic addressed by the joint group was that of definitions. Of the definitions that were listed in the Issues and Objectives Statements prepared by the EPA prior to the Workshop, the following were discussed and changes were suggested in order to make these working definitions more readily understood and useful to the Workshop participants:

1. Criteria, Environmental Radiation Protection - The environmental radiation protection criteria for waste management will be a generalized Agency policy statement detailing the basic philosophy, conditions, and issues that must be considered and reflected in the development of generally applicable environmental radiation protection standards and in the selection of appropriate waste management technologies and sites.
2. Public - Those individuals other than those Federal officials having responsibilities in the area of radioactive waste management.

Further, the term "low-level naturally occurring waste" was changed to "low-level naturally radioactive waste" to emphasize the fact that it is the radioactivity that is natu-

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rally occurring, as opposed to the wastes occurring naturally. The definition was not changed.

Two other definitions were discussed by the group as being useful for comparing impacts at disposal sites:

1. Intermediate-Level Waste - Wastes that have been treated, such as solidified liquids and high-specific-activity waste, and long-half-life materials not included in the definition of low-level naturally radioactive waste. (There may be exceptions with long-half-life materials occurring in nature which could appear in two categories, for example, discrete sources of radium-226. In such cases where the specific activity is high, such waste would appear in the most hazardous category, specifically, intermediate-level waste.)
2. Low-Level Waste - Waste of low specific activity or short half-life. (There is a need to clarify the anomaly that large amounts of short-half-life material be classified as "low-level." The site impact of large amounts of short-half-life material should be similar to small amounts of other material.)

One member of the group offered the opinion that intermediate-level and low-level should be defined in terms of specific numbers. There was also a strong opinion expressed relative to the urgent need to define a lower numerical value for what is and is not radioactive waste. No consensus was reached on the exact meaning of the above terms.

Participants felt that uniformity of definitions among the various agencies was essential and that specific, generally applicable, definitions should be developed. The group generally endorsed two definitions:

1. Waste, Radioactive - All retained radioactive materials for which no immediate or foreseeable use is intended generated as byproducts of human activities. These include (but are not limited to): high-level (HLW) and transuranic-contaminated waste (TRU), both produced through activities associated with military weapons production and nuclear power generation; wastes from medical and dental radioisotopic applications; uranium mill tailings; waste products associated with decommissioning activities; and mining activity wastes, such as phosphate tailings, in which appreciable quantities of naturally occurring radioisotopes are redistributed.
2. Management - A generic term describing the entire range of activities for dealing with radioactive waste, including processing, transportation, storage, and disposal. A given set of such activities and the

> technologies by which they are implemented constitutes a management system.

However, there were dissenting opinions within the group which questioned EPA's authority to set generally applicable criteria for all phases of radioactive waste management.

The distinction between "criteria" and "standards" was not sufficiently clear and, consequently, a good portion of the discussion in both sections of Working Group 2 was devoted to dealing with this difficulty. In many instances, after lengthy discussion, the group concluded that a particular issue was related to the development of "standards" rather than "criteria" and not appropriate for this Workshop. The concept of criteria as philosophical or policy guidelines was repeatedly reemphasized in order to confine the discussion to the proper issues.

Consensus was reached in both sections of Working Group 2 that generally applicable criteria for protection of man and his environment from risks from radioactive wastes should be developed. This consensus was reached rapidly with minimal discussion.

The following represents the reports developed by each of the sections of Working Group 2. Section A of Working Group 2 dealt with low-level naturally radioactive wastes, while Section B dealt with low-level and intermediate-level (man-made) radioactive wastes.

LOW-LEVEL NATURALLY RADIOACTIVE WASTES (MILL TAILINGS, PHOSPHATE TAILINGS, ETC.): SUMMARY AND CONCLUSIONS OF WORKING GROUP 2, SECTION A

APPLICABILITY OF CRITERIA

Consensus was reached by the group on the following points:

1. Consideration of risks to future generations should be included in the criteria.

   There was considerable discussion in arriving at point 1 about how far into the future one should go in such considerations. It was felt that methodologies and techniques for such evaluations were more relevant to standards and were not appropriate subject matter for criteria.

2. Criteria should take into account the possible effects of waste management on other components of the biosphere.

   There was little discussion in reaching a consensus on point 2.

3. Wastes should be managed in such a way that the risk to future populations should be no greater than we are willing to accept for ourselves.

   The word "population" was used rather than "generation," so that we would not be confined to an arbitrary time span. Consensus on point 3 was reached after considerable discussion of various viewpoints on the subject of risk to present and future populations.

4. Retrievability is not an issue that requires consideration for this category of wastes, i.e., low-level naturally radioactive wastes.

   There was considerable discussion about the meaning of "waste." The point was raised that what we now consider to be waste may be a resource in the future. The discussion led to the conclusion, however, that this consideration does not affect our consensus on retrievability.

5. Development of data bases is more appropriate to the formulation of standards rather than criteria.

   There was little discussion in reaching a consensus on point 5.

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The question of applicability of criteria to existing sites was addressed. Two viewpoints emerged. The first stated that standards for existing sites should be evaluated within the framework of criteria on a cost-benefit basis. The second viewpoint was that site distinctions are irrelevant to the formulation of criteria, since they are within the purview of standards.

CRITERIA CONSIDERATIONS FOR SITES

The question of site alternatives was addressed. It was pointed out that there may be alternatives available and that, where feasible, consideration of alternatives should be included in any evaluation of a waste management site. In any event, the question of site alternatives was not felt to be a subject for criteria development.

CONTROL OF RADIOLOGICAL IMPACT TO THE POPULATION

Consensus was reached by the group on the following points:

1. Criteria should require that maximum individual and population doses be taken into account in standards setting.

   Two opinions were expressed relative to point 1. The first was that in setting such standards, the work of the International Committee on Radiation Protection (ICRP), National Committee on Radiation Protection (NCRP), and other internationally recognized authorities should be considered. Others felt that no reference should be made to ICRP, NCRP, or other "recognized authorities" as this may imply acceptance of scientific dogma.

2. Natural background levels are the appropriate lower limits below which cleanup of an area would not be justified.

   There was discussion of the meaning of "natural" background levels. Natural background was felt to be levels that would have existed if there had been no activities by man.

   The question of limits on future uses of disposal sites were felt to be covered by the consensus point on risk to future populations. As for radon exhalation, it was felt that dose limit criteria recommendations and the uranium fuel cycle standard adequately cover point 2.

LONG-TERM CONSIDERATIONS

Three points were raised in this category relevant to the management of naturally radioactive wastes: maintenance of site integrity, surveillance and accidents. In all cases, it was the feeling of the group that the consensus point on dose to future populations and the magnitude of the problem on these points made unnecessary their further consideration in the formulation of criteria.

TOPIC 2, SECTION A: EXECUTIVE COMMITTEE

LOW-LEVEL NATURALLY RADIOACTIVE WASTES (MILL TAILINGS, PHOSPHATE TAILINGS, ETC.)

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Thomas Philbin*	Ecological Analysts, Inc.
Sally Rodgers**	Central Clearing House
Keith Schiager**	University of Pittsburgh

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* Moderator.

** Panelists for Plenary Workshop Session, 12 April 1977.

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LOW-LEVEL AND INTERMEDIATE-LEVEL (MAN-MADE) WASTES OTHER THAN THOSE DISCUSSED IN SECTION A: SUMMARY AND CONCLUSIONS OF WORKING GROUP 2, SECTION B

APPLICABILITY OF CRITERIA

Consensus was reached on the following points:

1. The criteria should generally apply to waste disposal. Existing disposal sites should be evaluated against the criteria separately and site-specifically. The following other points of view were also expressed:
    a. If standards developed under the criteria differ significantly from present standards, sufficient lead time should be permitted to bring existing sites into compliance.
    b. If serious differences exist between requirement of the criteria and existing site conditions, remedial steps may be necessary on an emergency basis.

2. The criteria should be a general statement of policy. Waste categorization should be an integral part of the implementation of the program.

3. The proposed criteria should address:
    a. Future retrievability (see point 2 under Long-Term Considerations)
    b. Future use of the disposal site
    c. Future use of the waste materials
    d. Present use of waste materials.

4. The following considerations are among those necessary for the development of adequate criteria:
    a. Potential risk
    b. Suitable containment
    c. Potential release
    d. Abnormal events
    e. Technical parameters such as volume of waste, inventory of radionuclides, etc.
    f. Aesthetic, historic, and recreational concerns
    g. Public acceptability.

There was disagreement in the group as to whether or not economic factors should be considered on the development of the criteria. Several people suggested that consideration should be given to the incremental costs of dose reduction. Other people felt that economics should not be a barrier to full protection. It was pointed out that criteria addressing

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decommissioning, long-term care costs and financing arrangements may be included within "economic factors."

CRITERIA CONSIDERATIONS FOR SITES

Consensus was reached on the following points:

1. Both environmental barriers (geological) and engineering controls may be necessary to provide the required protection to man and the environment. Primary reliance should be placed on the environmental barriers of the site. The specific site will determine the balance of engineering and environmental controls.

   There was a difference of opinion as to whether each disposal site should have a capacity rating for radioactivity which could not be exceeded. Several people felt that a capacity rating would result in proliferation of sites with increased risk since additional sites may be inferior to a well-planned but filled site. Other people felt that a limit on the capacity of any specific site would limit the risks in the event of any accident, intrusion, or other unplanned release and would facilitate decommissioning and site reclamation. The question what will be the basis for determining the need for new sites was also raised. The question was not discussed by the group.

2. There is no simple answer to the question: Are the relative advantages of the geology of drier regions great enough to support the trade-off between the reduced risk at such sites versus the increased risks and costs associated with the transportation of wastes to such regions? The answer would depend on the site, the amount and the radionuclide content of the particular waste, and the distance traveled. It was the feeling of the group that if all factors were equal, the waste material should not be transported to an alternate location.

3. There was considerable discussion on whether each area that receives a major benefit should handle its own low-level and intermediate-level waste disposal. The group took a vote on this issue. A majority voted no.

   The group discussed the question of whether states should be able to set more stringent criteria for environmental protection from intermediate-level and low-level waste than Federal authorities. There was an opinion expressed that there should be no Federal preemption in this matter.

The question was raised as to what mechnisms are required to prevent site disturbances that may produce environmental impacts. The group did not understand the question and accordingly did not discuss it.

CONTROL OF RADIOLOGICAL IMPACT TO THE POPULATION

Consensus was reached on the following points:

1. The limits, if any, which should be placed on future use of waste disposal sites will depend, in part, on the concentration and half-life of the waste materials, and on soil characteristics. It was recognized that this generation has relatively little control over the stability of future societal institutions. Therefore, the criteria should be adequate to reduce the risks for a specified future time.
2. The objective of waste management is to ensure that we do not pass on to future generations any risk we would not be willing to assume ourselves.
3. Segregation of wastes by half-life, activity, and/or other characteristics may provide a net advantage. Concern was expressed regarding the feasibility of segregating waste types.

LONG-TERM CONSIDERATIONS

Consensus was reached on the following points:

1. Site integrity should be assured as long as necessary to ascertain that the environment be protected from materials until they are innocuous. There was discussion that societal institutions should be relied upon to maintain this integrity for a limited time for other than tailing waste forms.
2. Retrievability of waste may have some utility at some time, but it is always to be considered secondary to safety.
3. Group discussion indicated that surveillance of a disposal site should continue for only a limited period of time. Primary reliance should be placed on environmental barriers and engineering controls.
4. The formulation of criteria should take into account the probability of accidents. It was suggested that remedial measures for an accident should be preplanned.

ADDITIONAL POINTS (SECTIONS A & B)

Other opinions presented but not discussed fully include the following:

1. Numerical standards resulting from these criteria should be developed in a public forum and not only by publication in the Federal Register and solicitation of written comment.
2. The linear, nonthreshold model of the biological effects of radiation, and the integration of population doses to infinity, should be used in assessing risk from radioactive waste management. There were strong opinions as to whether or not this was an acceptable technique for risk assessment. However, this was not pursued since the group felt this involved methodology related to setting standards and not to developing criteria.
3. Some expressed the view that the fundamental question underlying all criteria for radioactive waste management is: What level of insult are we going to pass on to future generations? Again, strong opinions were expressed against this view.
4. Risk reduction analyses should include the concept of relating cost of reduction to the magnitude of the dose reduction.
5. The National Environmental Policy Act (NEPA) should be applied to applications for low-level commercial waste sites and to mining and milling license applications in agreement states.

TOPIC 2, SECTION B: EXECUTIVE COMMITTEE

LOW-LEVEL AND INTERMEDIATE-LEVEL (MAN-MADE) WASTES OTHER THAN THOSE DISCUSSED IN SECTION A

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Anne Kunze	Friends of the Earth
Susan Lepow*	Environmental Protection Agency
Pete Tedeschi	Environmental Protection Agency

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* Moderator.

** Panelist for Plenary Workshop Session, 12 April 1977.

RESPONSE OF WORKSHOP PARTICIPANTS TO SUMMARY AND CONCLUSIONS OF WORKING GROUP 2

SUSAN G. LEPOW (U.S. Environmental Protection Agency Washington, D.C.): The first comment is from Ben Billing.

BEN BILLING (Environmental Action of Colorado, Denver, Colorado): The composition of this working group was mentioned, that is, industry people, EPA [Environmental Protection Agency] personnel, consultants, public interest people, etc. I request that the number of people associated with each category be read into the official record. Additionally, I request that all methods used to publicize this event, such as direct mailings, news releases actually published, TV coverage, etc., be read into the official record.

I just have one or two comments to make. To me it is very clear that the industry people here were well aware that this event was taking place, and yet you might say the public interest people were aware only on a very spotty basis that this event is taking place. And I think we also have to be very much aware that the industry people are arriving here on airplanes with expense accounts. This is part of their job, part of their job descriptions, and that this event is being held during the week which makes it very difficult for, you might say, adversary people or public interest people to show up at their own expense. And I think these kinds of considerations should be made very clear in the official record, which then at least helps others who are reading this official record to determine the overall validity of this proceeding.

LEPOW: We appreciate that. The next comment is from David Williams.

DAVID WILLIAMS (Americans for Rational Energy Alternatives, Albuquerque, New Mexico): I may just have misunderstood the point, but I thought I heard in there, language that seemed to be equating, that is, saying we should handle similarly, wastes involving large amounts of short half-life material and small amounts of long half-life material. First of all, was I correct in that reading? Because I would strongly disagree with it.

LEPOW: Why don't I ask the member of our group who raised that point to address your concern.

ALBERT L. BAIETTI (ICN-Chemical & Radioisotope Div., Irvine, California): The point in question was merely an anomaly to the operating health physicist when you talk about low level. We do not normally think in terms of large amounts, and the context with which the point was raised that we were trying to discuss site impact. And the feeling was that the impact on the site of short-lived material would possibly be no greater than the other kinds of material that would be included in the

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definition "low level," which was low specific activity. This was merely just a clarification point.

WILLIAMS: I see. Well my only point was that both the hazards and the problems of handling of large high specific activity low-level but short half-life material may be very different from the problems in handling and safeguarding low specific activity but long-lived material. For example, the latter you have to worry about containment over long periods of times and the former you have to assure a more rigorous degree of containment for a shorter time, and so forth.

LEPOW: The next comment is from Bill Perkins.

WILLIAM PERKINS (Atomic Industrial Forum, Washington, D.C.): This is a short clarification, off the subject, but I think it is necessary just for the record. I have not said anything earlier during the week because I think a lot of people here understand what has gone on between my statement Monday morning and what some of the press has said. But since it was in the record I would like to just clear it up very quickly. Monday morning I made several comments on the panel about the need for public acceptance of waste management. And one of the points I made that we have been discussing in general agreement all week in my Workshop is that the government should play a more forthright role, a more aggressive role in getting out more complete information about radioactive waste to the public. And along the way, to dramatize the need for this, I did cite several distorted and incomplete versions of the radioactive waste story that have gotten to the public lately through the popular press. Well, the story, the account of this, made the connection that I did not, that the press should not, and the government should, do all the providing of the information. Well, that was bad enough, then the headline came along and added the headline, "gag rule," to that, that you probably saw in the paper the other morning. Well, that was so bad that the reporter who is here in the room has actually apologized for that, for the headline. I understand since then there is even an editorial based on the subject, which I have not seen. I have spent my career, such as it is, in journalism and public information and it just astonishes me to think that anybody could think that the press should be prohibited from a subject and the government should force-feed it to the public, let alone to think that I believe that. So I urge all of you, if you still have any doubt, to read my paper. Thank you.

LEPOW: A comment from Ben Benally.

BEN BENALLY (The Navajo Nation, Environmental Protection Commission, Window Rock, Arizona): For any interested parties, whether government, industry or public interest groups--you are invited to observe or participate in the decontamination of the abandoned uranium millsite at Shiprock, New Mexico. Eighty percent of the site has been decontaminated and stabilized for future removal. This site could also be a guideline for future decontamination projects anywhere.

LEPOW: A comment from Marc Goldsmith.

MARC GOLDSMITH (Energy Research Group, Inc., Framingham, Massachusetts). There are logical inconsistencies between groups A and B. Group A decided to totally exclude site discussion from criteria and Group B came to the opposite conclusion. How do you justify the opposite conclusions as consensus?

LEPOW: What I read as consensus were the consensus of the separate subgroups. The one group was talking about mill tailings and the other group was talking about low level.

GOLDSMITH: Okay, so essentially there was no group consensus, and essentially unless both Group A and Group B are very clearly defined as to who participated and so on, then we cannot assume that that is consensus of Workshop 2.

LEPOW: What you have is the consensus of people that chose to talk about naturally occurring and the consensus of people that chose to talk about low-level, man-made waste.

GOLDSMITH: I would request that the record show who is in Group A and who is in Group B, along with the total Workshop grouping, so that we can understand who made those consensuses and who is involved.

LEPOW: Thank you. I think the affiliations as pointed out here are on the record and will be part of the proceedings as they were in Reston.

I would just add that we had people moving back and forth. I do not know that we will be able to provide that, but I recognize your concern. The next comment is from Lawrence Jones.

LAWRENCE JONES (The Pacific Legal Foundation, Washington, D.C.): Please explain why "acceptance of scientific dogma" should not be implied. Should not an objective of waste management also be to protect present society in such a manner that we pass on to future generations something?

CHAUNCEY KEPFORD (Environmental Coalition on Nuclear Power, State College, Pennsylvania): I was the originator of this idea of not relying on scientific dogma for all our answers. The example I will use is as following: In an April Federal Register notice, the Nuclear Regulatory Commission [NRC] dismissed a rule-making petition using the reasoning "that the hypothesis," (and in particular it was the particle hypothesis of Gofman and Tamplin and without referring to the validity or invalidity of the hypothesis) the reasoning used by the NRC was that the hypothesis was speculative and not supported by the scientific body of data and knowledge on the subject. Now if we apply these criteria to all new discoveries and ideas we will find that there will be no new ideas and no new discoveries because of course they will not be supported by the body of scientific data and knowledge on the subject. Indeed if we go back into history we will find out that minor discoveries, inventions, ideas and so on, like the wheel, the fact that the earth is round, fire, nuclear fission itself, the discovery of the nucleus, would not at the time of discovery be supported by the body of scientific data and knowledge on the subject. The stakes are too high. We cannot rely on dogma. Thank you.

LEPOW: The next comment is from Kent Zook.

KENT ZOOK (Citizens Against Nuclear Threats, Albuquerque, New Mexico): If the EPA was really doing its job of protecting the environment the focus of this Workshop would not be to establish criteria for the management of nuclear wastes. Rather the focus would be on the phaseout of nuclear energy and the management of currently existing wastes until technology can be developed to render them harmless.

LEPOW: Anything to add? Thank you. The next comment is from Keith Schiager.

KEITH SCHIAGER (University of Pittsburgh, Pittsburgh, Pennsylvania): The criteria should address the issue of a lower limit of radioactive contamination below which special waste management methods need not be utilized. The costs of site selection, regulation, specialized handling, long-term care and surveillance should be incurred only when they clearly reduce risks. Space in designated disposal facilities should not be taken up with wastes presenting insignificant risks from radioactivity.

LEPOW: The next comment is from Edith Kirby.

EDITH KIRBY (National Health Federation, Albuquerque, New Mexico): What long term insurance is available or planned for the people and their property and environment in areas of waste disposal? Insurance policies now recognize the unprecedented dangers of nuclear energy by excluding from their coverage damage resulting from it. Does this apply also to the wastes?

LEPOW: Would somebody like to address that?

J. STEWART CORBETT (Chem-Nuclear Systems, Inc., Kirkland, Washington): We operate a facility in the state of South Carolina and we carry what is called Nuclear Energy Liability Insurance Coverage, NELPIA, to the tune of one million dollars for each and every incident which can be attributable to a nuclear incident. The million dollar policies cover transportation and other events which might occur in the operation of our facility.

KIRBY: Do you consider that one million dollars on each incident is sufficient to cover the damage that does and could occur?

CORBETT: We have had nuclear, application of nuclear energy, since 1942. During that period of time there have been many claims placed which involved "nuclear" damage. To date there have been a minimal, maybe two or three, relatively minor claims which have definitely established a nuclear implication. It is extremely difficult to establish the fact that damage has occurred by virtue of exposure to radiation.

KIRBY: Is that not just the point?

CORBETT: I am not a medical doctor, and I think that we must recognize that, number one, every one of us in the room here ...I live in the Pacific Northwest, and by virtue of being here in Albuquerque I am receiving more radiation from the natural background than I would if I were at home. I cannot answer the question medically.

KIRBY: If this is true, why is it that other insurance companies which are in the business of insuring, and it is their business to know what risks are, exclude radiation damage or nuclear damage from their policies?

CORBETT: I would have to refer that question to a representative of NELPIA or NELIA, and I do not know if anyone from either of those organizations present might care to respond.

KIRBY: Thank you. The facts remain.

LEPOW: Ann Kunze.

ANNE KUNZE (Friends of the Earth, Alpena, South Dakota): Thank you. I have something I would like to recommend to EPA for action regarding its responsibilities for environmental protection. I believe that EPA should undertake a study to examine the various areas of responsibility and jurisdiction between the state and Federal government, state agencies in each state, and Federal agencies and institutions which have any involvement with radioactive materials, to make an analysis of the interfaces between each. The purposes of this analysis should be to identify any areas of overlapping jurisdiction or responsibility or any gaps which may create confusion or problems in protecting the public health, safety and the environment. This analysis should also determine how well any responsibilities for such protection is being carried out by each of these. EPA should then seek to devise plans and recommendations which would eliminate these areas of confusion, gaps, or inadequate actions which may exist. EPA should then undertake [an] affirmative action program to assure that any problems or deficiencies are adequately addressed so that no failure occurs in the system established to protect the public health, safety, and the ecosystem from the dangers of radioactivity. I think this is a serious problem. Just to cite one instance which may illustrate it: when I heard about the small explosion at the Hanford plant, it was just an incomplete announcement on the radio. It just said there had been a nuclear accident at the Hanford plant, which may involve any magnitude and any amount of danger. So I called [The Energy Research and Development Administration] ERDA in Denver and they referred me to EPA's Hazardous Materials in Spokane, so I called there and I asked about that and he said, "Lady, I wish I knew. I just know what they tell me and all I have is a press release. I am not allowed to know anything except what comes outside the fence." I said, "Well, if you are supposed to protect the public from hazardous materials and you are not even allowed to know except what you are told and you have only press releases, how can you do an adequate job of protecting the public health and safety?" It was just an illustration of the fact that there are gaps in communication, gaps in coordination, sometimes overlapping responsibilities in which both agencies may drop it. Or, for instance, in South Dakota now, due to financial difficulties caused by the drought, we have let loose of the only two state health mine inspectors that we had in the state at the very time when uranium mining is beginning to boom. So agencies may assume that there are things in place that are functioning, which are not even in place, although on paper they may be. I think that the best way to protect our environment, and public health and safety is to really do a definitive study of this and find out just what the situation is and where remedial action may be necessary.

LEPOW: Thank you. The next comment is from Judith Johnsrud.

JUDITH JOHNSRUD _(Environmental Coalition on Nuclear Power, State College, Pennsylvania)_: In view of repeated comments by attendees at this conference that there was inadequate advance notice of this EPA Workshop to enable full representation of citizens who are not affiliated with the nuclear industry or its regulatory agencies, I would register a request that EPA _not_ accept the definition of "public" that was accepted in working sessions of this conference and that is included in this report. I am referring here essentially to the issue of conflict of interest.

LEPOW: Thank you. The next comment is from Gary Armstrong.

GARY ARMSTRONG _(Citizen, Albuquerque, New Mexico)_: Comment on point 2, page 2-88. [I] disagree. [A] distinction should be made between natural and unnatural radiation. Since some radioactive elements do not exist naturally, man-made radioactive elements should not be considered "as if" they are identical. I would also like to say that what that says is that, number one, allows the background radiation to be doubled. I think that should be considered just in itself, because we are evolved within certain limits to adapt to radiation and this is going to double it. And number two, it ignores the theory of the accumulation effect of radiation, which says there is no safe level because all the radiation that we are exposed to can have an accumulative effect.

LEPOW: Thank you. The next comment is from Isaac Benton.

ISAAC BENTON (Citizens Against Nuclear Threats, Albuquerque, New Mexico): On the issue of voting to achieve final statements, I would like to point out that given the makeup of the conference (industry vs. "public") and the inability of much of the "public" to attend, voting to reach final statements is inappropriate.

LEPOW: Thank you.

BENTON: I just want to make a comment. I do not want to call into question any democratic principles. Rather I would like to see them enforced a little better. We, as members of the public, as opposed to industry representatives and government representatives here, are not able to, by means of voting, express our viewpoints. I feel that minority viewpoints should be expressed.

LEPOW: They are expressed.

BENTON: I know they are. I just feel that this procedure of voting is questionable.

LEPOW: Thank you. The next comment is from Susan Herman.

SUSAN HERMAN (Citizens Against Nuclear Threats, Albuquerque, New Mexico): Let it be shown on the record that yet another citizen feels that this was a farce of a "public meeting." How can private citizens be adequately represented when this conference was not widely publicized and it was held at an extremely inconvenient time for private citizens--during the week when most are at work.

LEPOW: The next question is from Jim Feeney.

JIM FEENEY (New Mexico Public Interest Research Group, Albuquerque, New Mexico): Can anyone explain how an agreement state program can be considered "compatible" with the Federal program without requiring a [National Environmental Policy Act] NEPA-style environmental impact statement [EIS] for state licensing of a low-level burial ground, when such an EIS is clearly required for [Nuclear Regulatory Commission] NRC licensing of such a site?

My comment is that the state of Illinois has a low-level waste disposal site, which in the state of Illinois is not an agreement state; NRC prepared an EIS for that site. If they were to open a site in New Mexico which is an agreement state, then the Environmental Protection Agency would not have to have an environmental impact statement prepared. Before I get a run-around from a government agency about why this exists, I know why it exists and I think it may have to be settled in the court. I just thought it was appropriate to bring it to the attention of this audience at this time.

LEPOW: Mr. Corbett.

CORBETT: Beginning at eight o'clock tomorrow morning, our company and all of our consultants are gathering, at which time we are going to draft our final document for submittal to the State of New Mexico. This document will be reproduced in copies approaching that which the EPA produces, approximately 100 copies. It will in effect be an environmental impact statement in support of our application to the State of New Mexico and will include all of those things which are normally required in Federally requested impact statements.

UNIDENTIFIED SPEAKER: I would beg to differ that the requirements in NEPA are much more stringent than the requirement of the Environmental Improvement Agency of New Mexico and they will.... The scope of it is much different than is being prepared by Chem-Nuclear.

CORBETT: We have in our possession, which is our guide, a six to seven page unofficial criteria from the State of New Mexico. One particular section of that criteria is Appendix A, which is a risk analysis and it goes into considerable detail specifically in this environmental impact area, or it will.

LEPOW: The next comment is from Gary Armstrong.

GARY ARMSTRONG (Citizen, Albuquerque, New Mexico): Under Topic 2, Section A, applicability of criteria proposal that criteria which used costs-benefit analysis include costs in terms of potential loss of human lives with accidents and unplanned events used as risk factors of primary consideration.

LEPOW: The next comment is from Frank Revera.

FRANK REVERA (Los Alamos Scientific Laboratory, Los Alamos, New Mexico): Radiological impact to the population: It appears to me that what is meant here is maximum permissible doses; without the word "permissible," --the criteria does not need the word maximum. And comment two: To set standards on doses without reference to [International Commission on Radiological Protection] ICRP and [National Council on Radioactive Protection] NCRP is ludicrous.

LEPOW: Anything to add? That's the end of our comments and I thank you.

TOPIC 3

PUBLIC ACCEPTABILITY OF THE RISK ASSOCIATED WITH RADIOACTIVE WASTE

PUBLIC ACCEPTABILITY OF RISK FROM RADIOACTIVE WASTE: A STATEMENT OF ISSUES AND OBJECTIVES

INTRODUCTION

"Public acceptability of risk" is a term prone to numerous interpretations, partly because of the contextual problem of what is meant by and how to gauge both public acceptability and long-term risk. While much effort and money has been expended in the past to develop mechanisms by which determinations of acceptable risk could be made, these were, to a certain extent, technical tools for technologists. Fundamental questions concerning the criteria and standards development process, as well as the technical issues identified by this process, have serious moral, social, and political ramifications which ultimately must be decided in the public* sector.

INTERACTION OF THE PUBLIC WITH THE WASTE ENVIRONMENTAL STANDARDS PROGRAM

The practice of the Environmental Protection Agency (EPA) with regard to public participation and review is exemplified in the Office of Radiation Programs' Waste Environmental Standards Program (WESP). For this particular program, provisions have been and are being made for even greater public involvement because of the number of critical issues which bear on public acceptability. As shown in Figure 1, public participation is both direct and indirect, the former being solicited in the Workshops and the latter through the Agency's public review process.

The format of the Workshops is designed to allow extended interaction between representatives of major sectors of society, including the unaffiliated public. The objective of such interaction is to: (1) define key terms associated with the waste problem and examine the basic concepts for disposal criteria; (2) consider available information on the risks associated with wastes and the long-term implications of radioactive waste management and disposal. As these Workshops are, by definition, publicly oriented, the social and policy aspects of all issues will be given special emphasis. All major viewpoints expressed for each issue will be recorded; those endorsed by consensus will be identified as such. The Agency recognizes the information realized from these Workshops as a significant resource in the formulation of environmental protection criteria for radioactive waste.

The public review process encompasses two modes: review of draft and final criteria and standards documents, as well

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* The public, as defined here, comprises those individuals other than Federal officials having responsibilities in the area of waste management.

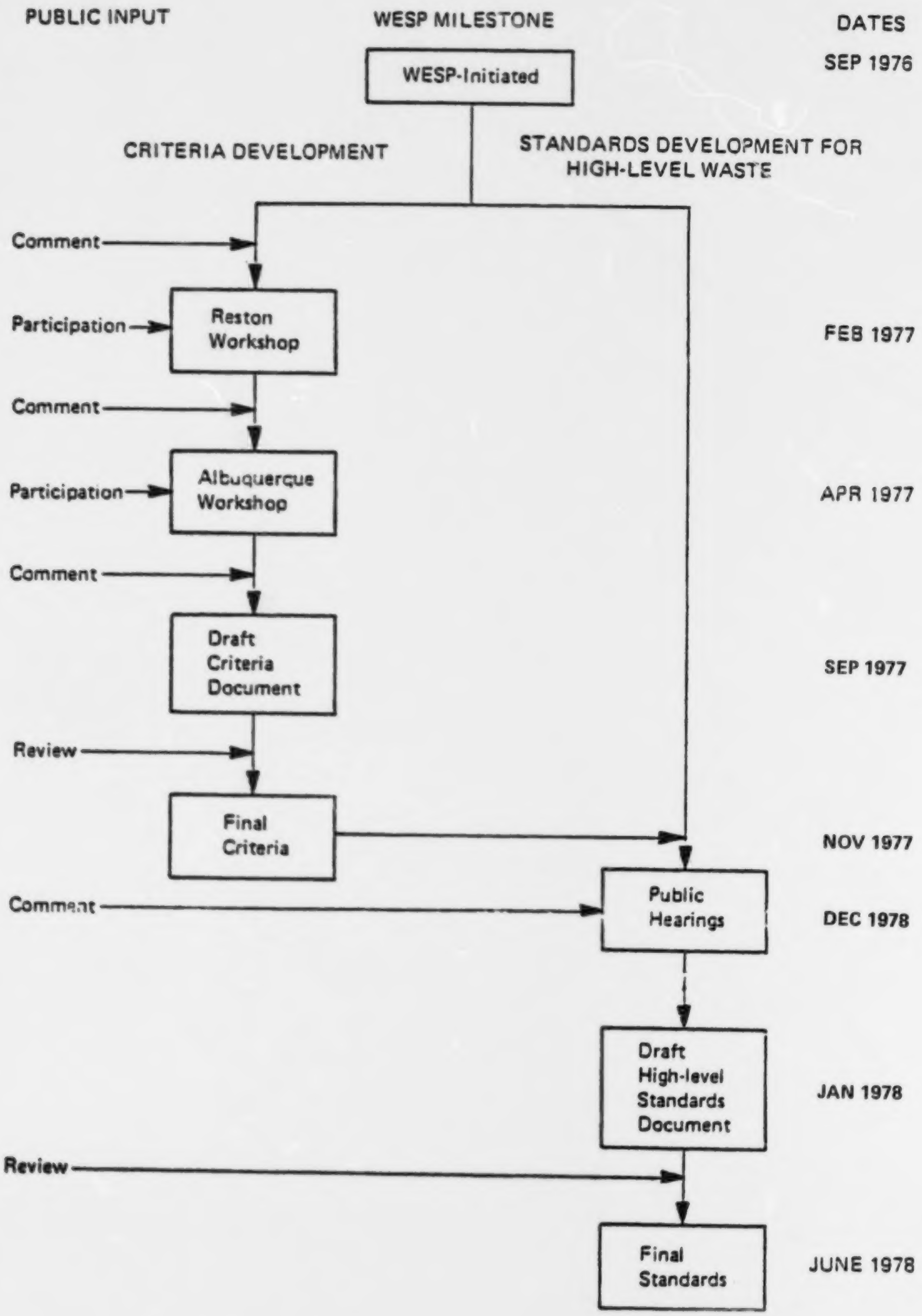
PUBLIC INPUT
WESP MILESTONE
DATES
WESP-Initiated
SEP 1976
CRITERIA DEVELOPMENT
STANDARDS DEVELOPMENT FOR HIGH-LEVEL WASTE
Comment
Participation
Reston Workshop
FEB 1977
Comment
Participation
Albuquerque Workshop
APR 1977
Comment
Draft Criteria Document
SEP 1977
Review
Final Criteria
NOV 1977
Comment
Public Hearings
DEC 1978
Draft High-level Standards Document
JAN 1978
Review
Final Standards
JUNE 1978

Figure 1. Waste environmental standards program (WESP) public review process.

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as a Draft Environmental Impact Statement; and public hearings on the proposed criteria and standards. Availability of documents upon request will be announced in the Federal Register. Formal comments will be solicited in the same manner, and will become part of the public record.

The first issue to be addressed is whether there may be alternate modes and opportunities for public input which would prove to be more comprehensive and productive than the program described. While there may be a number of such possibilities, all of them will hinge on one factor--how informed is the public? Is enough information, in a form compatible with a layperson's background, being provided via the traditional routes? What additional information is required, and in what form, to assure a high level of comprehension and confidence by the public? These Workshops are a means, albeit a limited one, to encourage such discussion among technicians and laypersons on a common level. Are there alternative mechanisms by which discourse could be improved, or are there perhaps more advantageous forms for the Workshop?

RISK CONSIDERATIONS

One of the issues this session will be asked to analyze involves bases of criteria which have been recommended to EPA that apparently are inconsistent with one another or have self-contradictory aspects. For example, the Reston Workshop participants recommended to EPA that, although priority should be given to criteria and standards development for high-level commercial waste, ultimately the risk from all types of radioactive waste should be considered with some degree of uniformity. An issue which follows from this recommendation is whether an acceptable approach based on both economic and technical considerations is possible. There are a number of possible approaches: a single environmental standard to be applied for all waste disposal activities; a standard for zero planned release (which the Reston participants decided would be more realistic than the ideal, but unattainable goal of zero release); a standard encompassing the tenet of as-low-as-reasonably-achievable (ALARA); and so on. Can any one of these approaches, however, be applied to all the various waste types, considering the high degree of variability in activity, half-life, and quantity to be managed?

High-level and transuranic waste can be irretrievably disposed of by state-of-the-art methodology so that the hazard potential is not likely to be realized. With low-level natural wastes, however, the associated risk, although relatively low, is both long term and difficult to control because of the mass of material involved. The risk is a function of both the integrity of environmental and engineeered barriers and the half-life of the material, which generally is short (less than

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100 years). While the risks to present populations can be minimized by management practices, such as stabilization and removal from population centers, little can be done to maintain such risk reduction over long periods of time. As inevitable failures in these barriers occur over the years, the likelihood of exposure will increase steadily to a point where it is offset by the radioactive decay. Land dispersal or ocean dumping as a means of control would only serve to provide for a maximum dose commitment with no possibility of retrieval. Thus, assuming available technology, the risk posed by such disposal is likely to be borne by the next few generations, during which time institutional controls are likely to be more effective.

Against this background, then, would zero planned release be realistic for all wastes in general; or should it be considered as a goal, as suggested at Reston, which future technology may be better able to address? Would ALARA be an equitable solution or would it, in fact, lead inevitably to a nonuniform approach dependent upon the state of control technology for each waste type? As noted by a number of participants at Reston, uniform criteria and standards for all radioactive waste may be an idealistic goal for which no common denominator can be found.

Related to this issue of applicability is the question of whether environmental protection criteria and standards should apply to accidents and unplanned events irrespective of waste type. A view was expressed at Reston that if accidents and unplanned events are to be included for high-level waste criteria development, then the intent should be to make a general practice of this for all wastes. The difficulty again is in establishing a common basis for assessing risks. For example, how should the high-consequence, low-probability accidental risks of high-level waste disposal be compared with the relatively low-consequence, high-probability risks associated with low-level waste?

In addressing the issue of risk acceptability for radioactive waste, invariably risk will be compared to other comparative risks present in society. Although participants in the Reston Workshop recommended such an approach, is it, in fact, feasible, considering the unique nature of radiation as compared with other toxic substances? (The EPA subscribes to the linear, nonthreshold hypothesis, which holds that any exposure to radiation results in some health risk.) Assuming that the public is willing to accept a degree of risk as the price all of us must pay for the benefits of nuclear technology, what level of risk, if it can be quantified, would be acceptable? Conversely, how will those risks of an unquanti-fiable nature, such as those resulting from human activities (sabotage, excavation for other purposes, etc.), be addressed?

The Reston group was in agreement that acceptability of risks was to be determined by decision makers and/or the public. The role of risk assessors is to provide them with a framework for the best possible understanding of radioactive disposal risks with which to determine acceptability. However, no risk assessment methodology was identified as most effectively satisfying this criterion. Of the possibilities available, including cost/benefit, risk/cost, fault tree, event tree, comparison, etc., it is necessary to determine which is the most applicable and functional for radioactive waste.

An issue relating to site selection is the geographical apportionment of risk. Because of favorable geologic, demographic, and/or economic factors, various localities of the country have been and will be chosen for radioactive waste disposal. Can the affected segment of the population, those individuals bearing the risks associated with such siting, be expected by the remainder of the public to accept such risks without compensating benefits? Should local views form the basis of whether the risks are acceptable, or should the views of the broader public prevail? Are they separable?

LEGACY CONSIDERATIONS

The public acceptability of the long-term implications of risk is relevant to deciding the form and ranges of applicability of the environmental protection criteria. The Reston Workshop made a number of recommendations which need to be addressed in this context. For example, it recommends that radioactive waste disposal solutions should be independent of the stability of societal institutions, and also that the criteria should not be keyed to any single waste form or disposal method. However, the economic impact of assuring such institutional independence for some waste forms may be unacceptable. Should consideration of risk for all radioactive waste, therefore, be based on the time frame of concern appropriate to each waste category, and should decisions on institutional dependency and retrievability then be based on the cumulative risk over these time periods?

This concept is best illustrated in Figure 2, where degree of risk is qualitatively plotted versus time. The cumulative risk is then equal to risk x time, or the area under the curves. It is obvious, even on a qualitative basis, that considering risk on this basis could lead to altered perceptions and priorities. Again, because of the variability of half-life and state-of-the-art control techniques, the long-term implications of waste disposal vary by waste type. For future generations, short-lived, low-level wastes may not pose a hazard, whereas low-level natural and high-level radioactive wastes could. It may be necessary to choose a finite period of time over which appropriate control based on these considerations can be assured. Again, it may not be feasible to develop uniformity with regard to all wastes.

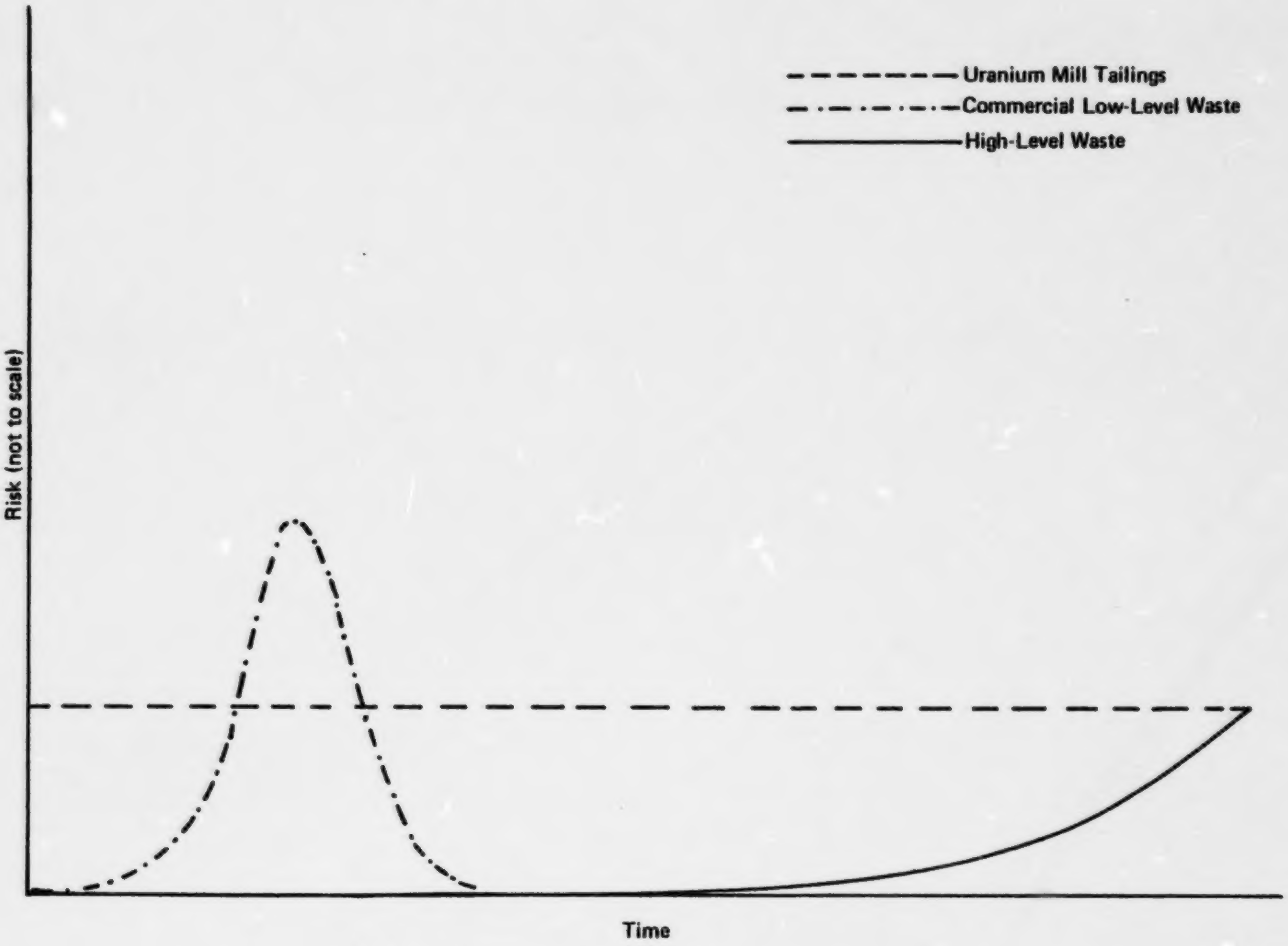

Figure 2. Time dependency of risk from radioactive waste.

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The Reston working group addressing the long-term implications of radioactive waste recommended that, if practicable, options should be left open for future generations to improve upon our program of waste management. However, this implies a responsibility to inform future generations of the risks passed on by the present one. Are the risks necessarily enhanced in the process? A decision as to whether record keeping or concealment is more practical and ethical needs to be made.

Related to this question is one concerning our responsibility in establishing and maintaining a monitoring program to ensure that acceptable levels of risks are not exceeded. Again, will the information provided by such a program reduce the long-term risk sufficiently to offset the disadvantage of marking the disposal site? Since such a program is predicated on institutional stability, should one design only for the short term?

A broader consideration bearing on public acceptability is determining what society requires of its institutions in terms of research and development, and regulation to assure public health and safety and environmental quality. Do rules and regulations issued by such institutions have much effect on the level of public acceptability of a technological solution? It is necessary to address these questions in the context of the historical perception of nuclear energy and radioactive waste? There appear to be three major factors underlying the public's perceptions: the evolution of nuclear energy from a weapons program shrouded in secrecy; the persistence of a certain "mystique" concerning its application and development resulting, in part, from security restrictions and the small number of individuals privy to relevant informaton; and the enforcement of stringent safety and environmental regulations on nuclear activities, thereby establishing a precedent for institutional responsibility beyond that of other societal activities.

For radioactive waste, in particular, there appears to have evolved a general lack of confidence in public institutions, primarily because of public uncertainty concerning disposal site selection and the publicity surrounding leakage from operating sites. The affected citizenry, to a large extent, believe that their views were not solicited and addressed properly. It would appear that the challenge to technology, as it relates to this problem, is to establish credibility with the first and perhaps second generations of the concerned and affected public. Once solutions are implemented, assuming that the institutions charged with the responsibility maintain their credibility by demonstrating responsible maintenance and capabiliy, new problems will tend to dominate the public's attention.

There may or may not be a conflict between the technical resolution of the radioactive waste management problem and public

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acceptance of the resolution. It is becoming apparent, however, that at least some segments of the public are not readily convinced that radioactive waste mangement is safe in the hands of technology. It may no longer be assumed that the public at large has confidence in technology or in technolgists. In order to rectify this situation, it may be necessary to incorporate overconservatism in technological design, and in criteria and standards development. As such an approach has a cost implicit in its application, however, higher expenditure and inflation may accompany the achievement of a risk level acceptable to the public. How much is the public willing to pay, technologically and economically, for an acceptable solution to the radioactive waste problem?

A final matter for this Workshop to address is the public's perception of the level of risk that may acceptably be passed on to future generations. The present generation has been exposed to risks that have their origins in the actions and activities of previous ones, such as the fallout originating from atmospheric weapons testing in the 1950s and 1960s. With the understanding that these wastes resulted from activities that played an integral role in our technological legacy, what level of risk, if any, would we accept from previous generations if given the choice?

To summarize, consideration of long-term impacts is replete with uncertainty. Our decisions will be based on our own perceptions formulated during a small segment of a time continuum. We are forced to make assumptions regarding how future generations will view risk (the same as we do), on their intelligence (equal), and the stabiity of their institutions (nonexistent), in order that these significant decisions can be approached with appropriate conservatism. On the other hand, it is certainly possible that cancer may someday be curable and, likewise, that technology may have progressed to the point where radioactive contaminants are easily extracted from water supplies. Although speculative, this suggests that perhaps our focus should not be on future generations at the expense of present ones and that a balance of some kind is necessary.

SUMMARY OF CONSIDERATIONS

Interaction of the Public with EPA

1. What information, and in what form, is required to assure a high level of public comprehension of major issues and to produce confidence in the process of developing criteria and standards?
2. Are there alternate modes of public participation which would prove to be more comprehensive and productive than those currently being used by EPA?

3. If technological and regulatory overconservatism is to be incorporated into the criteria and standards development process to ensure its public acceptability, will the higher costs and inflation implied be acceptable?

Risk Considerations

1. How should the risks from different radioactive waste sources be taken into account in developing criteria applicable to all wastes? Also, should accidents and unplanned events be considered for all waste types?
2. Should the risk posed by radioactive waste be considered in the same context as risks from other hazardous materials present in the environment?
3. In what framework should quantitative risk assessments be performed in order to provide the best possible understanding of radioactive waste disposal risks to decision makers, and to the public?
4. Can the affected segment of the public be expected by the remainder of society to accept the risks from radwaste disposal without compensating benefits? Should local or national views determine acceptability? Are they separable?

Legacy Considerations

1. Should consideration of risk for all radioactive waste be based on the time frame of concern appropriate to each waste category, and should decisions on institutional dependency and retrievability then be based on the cumulative risk over these time periods?
2. Do we have the responsibility and the means to inform future generations of the risks passed on from the present? Would the risks to them necessarily be increased by doing so?
3. What does the public perceive as an acceptable level of risk to pass on to future generations? Can such a decision be based on what risks the present generation is willing to accept?
4. What are the public's expectations for institutions whose responsibility is the long-term assurance of the public health and safety and protection of the environment, with regard to research and development, and regulation? Do the rules and regulations issued by such institutions have a significant effect on the level of public acceptance of technical solutions?

TOPIC 3 GLOSSARY

As-Low-As-Reasonably-Achievable (ALARA) - As low as is reasonably achievable, considering the state of technology and the economics of improvements in relation to benefits to the public health and safety and other societal and socioeconomic considerations.

Engineered Barrier - Any medium of containment of human manufacture, such as containers or solidification matrices, which stops or significantly retards the movement of radionuclides to the surrounding environment.

Environmental Barrier - Any medium of containment, either natural or engineered, which stops or significantly retards the movement of emplaced radioactive materials to the environment.

Linear, Nonthreshold Theory - The theory that postulates that any exposure to radiation results in some health risk, the degree of risk being proportional to the degree of exposure.

Public - Those individuals other than the Federal officials having responsibilities in the area of radioactive waste management.

Public Acceptability - The willingness of the public to assume a risk or cost associated with a technological problem.

Public Credibility - Public confidence or faith in the ability of an institution and/or society to satisfactorily solve a problem.

Risk - The general concept of "risk" includes the probability (or possibility) of loss, damage, or injury and the consequences (or magnitude) of the loss, damage, or injury. A common representation of risk is: risk equals probability times consequence.

Risk, Acceptable - Can be defined only with reference to the reason for taking the risk; a risk becomes acceptable at the level at which it reduces a competing risk by an equal amount, or is otherwise fully compensated.

Uranium Fuel Cycle (UFC) Standard - Generally applicable standards (40CFR190) that limit the allowable public radiation exposure and the quantities of released radioactivity due to normal operations of facilities comprising the uranium fuel cycle (LWR), excluding mines, transportation, and waste repositories.

Zero Planned Release - A design criterion such that leakage of radioactivity across any barrier is not anticipated.

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RADIOACTIVE WASTE AND PUBLIC ACCEPTANCE

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As I understand it, this session is quite different from most at technical workshops, including the other sessions here this week. They are typically "breaking-down" exercises, taking a complex problem and subdividing it into its smallest constituent parts, examining and quantifying them, and then putting them back together to understand the whole. To deal adequately with this subject, as this session demonstrates, I believe we must look outward, not in, and try to place the issue of radioactive wastes in the social and political context of our time.

It's a notable step forward that a technical agency in Washington is opening itself up to deal with the public acceptance aspects of such issues. Ten years ago, it would not have happened. Even today there are few precedents. It's also notable that the subject matter for this pioneering effort is, once again, nuclear power, which has been on the forefront of a number of social changes in the past decade, including public participation in decision making--not always voluntarily, but on the forefront.

The subject of this session is no less than one of the great dilemmas of our time; that is, how can the public constructively participate in major governmental and social complexities, to their own satisfaction? The very vagueness of the question demonstrates the difficulty of answering it. Who, really, is "the public"? What "constructive" participation can the public be expected to bring? Can participation at any level be satisfactory if the decision itself is not? These questions are unquantifiable and probably unanswerable, and I wouldn't presume to have any definitive solutions. But after 10 years of closely observing and working in nuclear public affairs, I do have a few facts, ideas, and questions that I would like to present.

PUBLIC PERCEPTION

Our text for the day could well be Harvey Brooks' prediction that "should nuclear energy ultimately prove socially unacceptable, it will be primarily because of the public's perception of the waste disposal problem." I believe that his statement is arguable. The same warning could have been issued in 1970 about low-level radiation and thermal effects, or in 1973 about emergency core cooling systems and reactor safety. There has always been a major central issue in the nuclear

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debate. As new information has developed and new facts adopted, however, each has been replaced by another. Today the central issue, at least in Washington, is not radioactive waste, but the threat of plutonium proliferation.

The key phrase in Brooks' sentence, though, is "the public's perception of the waste disposal problem." As we have seen with many issues in the nuclear debate, the facts are often less important than the public perception. That seems particularly true of radioactive waste management. I have met few observers of nuclear power, policy makers, or even critics who genuinely believe that the safe handling and disposal of radioactive wastes is inherently impossible. Most seem to recognize that this aspect of nuclear power lends itself to conventional engineering and management approaches that routinely deal with other hazardous substances. The recent Ford Foundaton report, Nuclear Power Issues and Choices, which was produced by a team of 21 independent experts with no involvement in nuclear power, concluded that "nuclear wastes can be disposed of permanently in geological formations in such a way that there is very little prospect of material escaping into the environment." In fact, this committee had such high confidence in our ability to handle nuclear waste that it suggested that the United States manage the spent nuclear fuel from reactors in other countries if that would help control proliferation.

THE PUBLIC'S ATTITUDE

One of the few quantifiable parts of the question we are considering is the public's attitude toward waste management. I'm sure that Burns Roper will be providing details about this aspect, but I would like to offer the results of one recent survey to indicate that we can't be sure of the answer even in this area.

In November 1976, Louis Harris and Associates released the "Second National Survey of Public and Leadership Attitudes Toward Nuclear Power Development in the United States," sponsored by Ebasco Services. In general, the report demonstrated a greater public concern about the energy crisis than political leaders recognized, and a greater public support for nuclear power--about a 3 to 1 margin. More to the point of this session, though, were several questions about radioactive waste management.

At first glance, it appeared that waste management had become a major issue of concern with the public. The sample was asked if they considered the disposal of radioactive wastes for centuries to become a "major problem." Sixty-seven percent said they did, a sizeable majority--and the largest percentage of any single issue.

On closer examination, though, the significance of that number tends to diminish. More than 50 percent of the sample described four other issues as "a major problem," including the needless worry about a nuclear explosion in a power plant. To determine the public's real concerns, it may be more significant to examine the issues that they volunteered. These appeared in several forms.

Those polled were asked to cite two or three main disadvantages of nuclear power plants. Radioactive waste disposal was cited by 13 percent, placing it fourth in frequency after unspecified dangers, radiation leaks, and reactor accidents. Interestingly, this disadvantage was cited first by political leaders, regulators, and business leaders.

Again, those polled were asked the reasons for their approval or opposition to nuclear power plants. Only 3 percent cited radioactive wastes--the same percentage that mentioned radiation leakage and less than that which listed accidents (4 percent) and a general fear of danger (14 percent).

In another section the sample was asked why they favored or opposed nuclear power as a main source of electricity in their community. Only 2 percent of the public mentioned wastes, less than those who cited radiation, accidents, other energy options, and general fear. These statistics do not mean that waste management can be dismissed as an issue of public concern, but neither do they indicate that it is one of the burning national issues of the day.

WHO IS THE PUBLIC?

The most difficult part of our question is a simple one: Who is the public? Or, for that matter, who represents the public? For most of my talk I have assumed that the public is just that--the tens of millions of men and women, of all ages, interests, education levels, and lifestyles that make up our country. Obviously, no rational technical program could even pretend to accommodate all their views--especially since the vast majority has no interest in the subject. In the Issues and Objectives paper that the Environmental Protection Agency (EPA) provided for this session, the term was redefined as the "concerned and affected public." This is a more realistic description of the participants in most decisions involving the public. But it should be recognized, then, that the participants outside the normal decision-making process do not generally represent the disinterested public, but a range of other special interests--scientists interested in the technology, labor officials interested in jobs, landowners interested in property values, nuclear critics interested in any issue that may provide yet another stumbling block to nuclear power. All of these viewpoints have their place, but it would be naive to believe that any truly represent the public. Or, for that matter, that even a consolidation and compromise of these ideas represents the will of the public. The concern, of course, is that procedures will be established in the name of public participation that can then be abused by special interest groups to delay and obstruct decisions after they are seen by most parties involved as in the best interests of the public. No matter how much participation by various publics is allowed, there must be a point of decision, based on the best evidence rather than rhetoric, after which further obstruction is quite difficult.

THE PUBLIC'S INFORMATION

One of the specific questions for this panel relates to the amount and type of information that should be made available to the public. First, though, I think we should consider the sources of current public information about waste management. If radioactive waste has become a major public concern, what information is the concern based on?

The answer is fairly obvious, based on basic observations about our society and on any number of surveys. Except for such specialized groups as scientists, industry employees, and environmentalists, the general public receives virtually all its information about such subjects as waste management from the popular press.

This is not the place for yet another diatribe against the press. As a journalist by training and inclination, I often reflect that the only industry in the country under more criticism than nuclear power is the press. We all know what is wrong with the popular press--as does the press. Because of higher education levels, increased leisure time, and instant communications technologies, the media have become a more powerful force than ever before. Yet they have not been able to shed the bias that has always been with the popular press--not a bias towards liberalism, populism, or any other ism, but simply a bias toward what has been called the melodramatic. That is, an overriding interest in stories pitting the forces of good against the forces of evil. The nuclear controversy, with its emotionalism, its polarized positions, and its importance, is tailor-made.

There is little that can be done about the press's handling of these subjects, especially the most powerful elements--the three television networks. But the press's role in public opinion has a few direct implications for any consideration of public attitudes toward radioactive wastes.

For one, the source of information must be considered in weighing the significance of opinion polls and other public attitudes. An apparent increase in public concern could simply be reflecting an impassioned series of advocacy articles in a newspaper chain, or worse, that incredible hour aired by the National Broadcasting Company television network in January, replete with graveyard images and deformed children. Such hysteria on a network can be extremely effective, as we've seen again and again, in impressing its audience. When parts of that audience then pass along their outrage, regulators and public policy officials need to be aware of the source and to give it the weight that it appropriately deserves.

Another consideration is the reach of the media. That NBC special was a failure in the ratings, by television standards, because it dealt with a fairly esoteric subject opposite Helter-Skelter and Roots. Still its audience for the hour numbered some 10 million--which is probably many times more than the total audience that government and industry have ever reached in such detail about radioactive waste. This dramatizes the relatively small public information programs that have dealt with waste management.

Because waste management is a Federal government responsibility, industry has hardly any public information programs dealing with it. And the few industry activities that include waste operate at extreme peril, since the government's plans and approaches have been known to change overnight without advance notice. The government's public information programs, headquartered in the Energy Research and Development Administration (ERDA), seem to consist of a couple of brochures available on request and some contact work with officials in states under consideration as waste management sites. With Congressional committees scrutinizing every activity that smacks of nuclear promotion, ERDA's reticence is understandable. Nevertheless, it leaves a vacuum of information for the general public that is being filled by network sensationalism.

WHAT TYPE OF PUBLIC INFORMATION

What kind of information about waste management should the public receive? This, again, is a more difficult question than it would first appear. There is no doubt that most of the public could understand the subject of radioactive waste adequately to make an informed decision, if they had easy access to all sides of the question or if they took the time to search it out. But the public at large does not. Considering the competition for time and effort today, as well as the other important issues that affect us all, I'm not sure that the public at large should invest its time to become experts on radioactive waste. I consider my time too important to spend it studying liquefied natural gas tankers, or saccharin, or aerosol spray cans in the detail that would allow me to make a truly intelligent decision. Most people obviously feel the same way about radioactive waste.

Still there is a continuing low-level interest on the part of the general public, and therefore a need for a program that allows them to understand the issue without a thorough background in radiation effects, chemistry, geology, and nuclear physics. That would require the predigestion of this information by a credible source who could, in lay terms, describe the issue in the proper perspective.

That, I contend, is exactly what is missing from the current debate over radioactive waste: the credible source and the perspective. Like most of the nuclear controversy, this issue is presented in the terms of two extremes--absolutely dangerous or absolutely safe--because all parties have become so completely polarized. Even independent scientists and professors find it nearly impossible to avoid being labeled 100 percent for nuclear power, or 100 percent against it. A moderating voice must be found to sort out the overstatements on both sides--and, especially in the area of waste management, that voice must be the Federal government. After weighing all the facts and viewpoints interested in nuclear waste management, the government must come up with a firm decision based on the best information available and be willing to advocate it as the agreed-upon national policy. Hoping that the country will come to understand the subject through osmosis or continuing to speak with various points of view will only perpetuate the current confusion and controversy. Somehow, despite the various interests of the agencies, the government needs to demonstrate its own confidence in waste management programs and present them to the public more consistently and effectively.

The most appropriate way to consider and present the issue of waste management, I believe, is in the style of this session rather than typical technical approaches. That is, not by presenting detailed technical facts in a vacuum, but in the full context of the benefits and risks of nuclear power and its alternatives. This context is usually absent from discussions of radioactive waste, just as it is here today, but it is a perspective that needs to be emphasized. A radioactive waste repository, alone, has no societal benefit, and it would seem that any risk is too great. The public needs to be reminded that the repository is directly tied to the benefits of nuclear power plants. Moreover, waste management programs of almost the same size would be required even if there were no nuclear power plants, because of military activities that create considerably more radioactive waste; the benefits are made possible by a small incremental risk. Similarly, a discussion of the risks of waste management can be complete only with a consideration of alternatives--the risks of other sources of power, or of the alternative of no nuclear power. Any context but the broad one of relative risks and benefits is an incomplete one and overemphasizes what has been called the unique risks associated with radioactive wastes. In fact, the uniqueness is the public's perception. Important as that is, it should not deter regulators and public officials from their basic responsibility--to develop policies based on real risks, real benefits, and real facts.

The perception of the public, as opposed to technical facts, must not be underestimated as an important contribution to such decisions. A number of surveys has shown that the basic assumptions and values of technologists often vary markedly from that of the general public, and even more so from those of people who consider themselves environmentalists. It is this different set of assumptions and values that the public can contribute to decisions such as this one, and these values can lead to a questioning of basic premises that has often been missing from such procedures in the past. Still, it must also be kept in mind that the participants from the public are usually not disinterested, but members of their own special interest groups; that their sources of information may or may not be valid; and that their perspective might be a constricted one. Public officials must weigh all of these contributions, while making their decisions based on the best available information and in the context of alternative options. After the decision is made, it should be pursued and advocated diligently, minimizing the opportunity for continued obstructionism and giving the public at large a reason for confidence in the decision and in the program.

ENHANCING PUBLIC ACCEPTABILITY

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I was invited today to give California's experiences with nuclear waste disposal and the formulation of public policy as it evolved through the development and implementation of the California nuclear waste disposal statute.*

Rather than presenting a lengthy discussion of California specifics, my intent is to touch briefly on our work and then develop and expand a hypothesis on the concept of publc acceptability of risk from nuclear wastes. Such a concept includes differing characterizations of acceptability, the nature and role of the public and private agencies involved, and my perceptions of the evolution of both legislative and regulatory policy. Some suggestions for a transition from the current state of public apathy/apprehension and mistrust to a state more conducive to public acceptance will be proposed.

Before beginning, I want to express my apreciation to the Environmental Protection Agency (EPA) for inviting my comments. I can't emphasize strongly enough the importance of the role EPA has. Involvement of an independent environmental regulatory authority is an obvious first step, indeed prerequisite to gaining any public acceptance. Those expressing strident disapproval of EPA's involvement (as evidenced in Reston) provide a superior example of the lack of perception of the nature and importance of such public acceptance.

CALIFORNIA

In June 1976, the California legislature passed and Governor Brown signed three bills addressing nuclear power. One specifically deals with waste disposal, disallowing future siting of nuclear plants until a finding has been made that the technology for disposal of high-level waste exists, is demonstrated, and has been approved by the authorized Federal agency. The findings are to be made by the California Energy Commission and are subject to review by the legislature. The

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* I speak today only for myself. The thoughts I have are my own. Relative to issues currently before the California Commission, I have not and do not intend these remarks to be determinative of my views as to ultimate issues much as they have been established by resolution, hearing order, staff work plan, and technical analysis associated with those proceedings.

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Commission has under way now generic hearings on both waste disposal and reprocessing, the first stage of which entails extensive informational hearings on the details and implications of the back end of the fuel cycle. The eventual outcome of the generic proceedings will be to make findings either positive or negative as to the efficacy of proposals to solve back-end problems. It is our current intention to hold to a time schedule which complements the Commission's decision on the siting of the first nuclear plant subject to our jurisdiction.

At this point, I would prefer to depart from California specifics (I will, if interest arises, talk more about California specifics in the Workshop sessions) except for one further point: California's effort (as is EPA's here) is predictably coming under fire from some quarters. We are rebuked for being holistic, criticized for looking at the larger context within which we make waste disposal and reprocessing findings, for intervention in the Generic Environmental Impact Statement for Mixed Oxide (GESMO), and for requesting coordination of Nuclear Regulatory Commission (NRC)-California siting timelines. We are allegedly disrupting and jeopardizing the future out of either naivete or zealousness, apparently because we haven't "designed a plant, raised capital, built a business, or met a payroll" (Ref. 1).

The tone of the criticism reminds one of an 18th-century French aristocrat discussing universal suffrage or other demonstrable social outrages. Not being regulated by Jim, Jack, and Mark, and regulation which cannot be privately predetermined appear abhorrent to this particular point of view. Reality is relative and acceptance essentially preordained.

As an interesting aside, in order to fully understand the nature of our decision, we did include background on the no-reprocessing option, alternative reprocessing techniques, and on the relationship between reprocessing and the anticipation of the breeder economy. In light of the recent position expressed by President Carter, it seems that these issues are not only timely now but demonstrated unbureaucratic foresight.

Our Commssion's critics represent the same posture as EPA's critics and they are crucial participants in the waste disposal controversy. I believe some insight into their nature is essential for any public acceptance deliberations.

The California Energy Commission is, of course, blessed by typical bureaucratic bumbles (recalling that Lockheed, Penn Central, and other giants are no less bureaucratic and probably more incompetent), and granted we don't raise capital and meet payrolls. However, development of nuclear energy and its fuel cycle has been wholly dependent upon government technology (i.e., enrichment and waste solidification) and largely dependent on initial government capital. Thus, while some critics heave mortar shells at bureaucracies, they quite appropriately, I believe, can be characterized as parabureaucracies themselves.

The parabureaucracy concept is of importance because these entities have and will play a large role in the waste deliberations, particularly relating to public acceptance. The exact nature and extent of their role should be a matter of major significance; mistaking "parabureaucratic acceptance" for "public acceptance" may disallow any successful resolution of the disposal controversy.

CHARACTERIZATIONS OF ACCEPTABILITY

In the interest of clarifying what public acceptance is, I offer three distinct concepts of acceptability: engineering, marketing, and public. A brief discussion of each follows.

ENGINEERING ACCEPTANCE

The concept of acceptance which pervades the current deliberations can best be characterized as "engineering acceptance." Such engineering acceptance takes the form of the conventional engineering wisdom--that all problems are subject to the scientific method and engineering principles, if time and money are available to discover and resolve them. Mastery of a technology is defined as conceptually understanding it and then merely applying engineering extrapolation to estimate both full-scale as well as commercial application. The bugs can then be worked out in stream. This presupposes that the current knowledge is not only adequate but complete and that paper exercises can in many cases cut corners and expedite the sometimes laborious process from test tube to product.

Since nuclear has had to be better than other product lines because of the inherent nature of the technology, both intense pride and competence have been developed along with intensive regulatory scrutiny to assure that such scale-ups are indeed what they purport to be.

This attitude, of course, has resulted in some mistakes, but all in all it has expedited a new technological innovation out of whole cloth.

Parallel operations, of course, with equivalent governmental scrutiny and idealism abound. The best analogy is perhaps major weapon systems development and deployment by the Department of Defense and its contractors, currently competing in a billion-dollar market for ever dwindling funds. However, the record in our analogy is fraught with problems in economics, engineering extrapolation, and even misdirected first principles. Yet if we spend enough, we are presumably secure or at least create the illusion of security which, of course, is all that is necessary in a stalemated world military situation.

Such is the nature of engineering acceptability. It is typified by the confident assertions of the early sixties of the "safe, clean, cheap," light water reactor (LWR) system. The accepted truth is internally consistent because the system talks essentially to itself, and technological optimism is omnipresent. In waste disposal, the familiar litany includes "the technology is in hand--regulatory indecision and public misperception are the problems."

This somewhat absolutist approach has its own disadvantages since the fears which the public may have are vicariously amplified by disclosure of minor errors by public bodies charged with responsibility to represent as well as protect the public interest.

MARKETING ACCEPTANCE

A second version of acceptance can, for lack of a better label, be termed marketing acceptance. It is evidenced when a particular concept (i.e., waste management is not a problem) is plausible enough, and financed to the point where the public information arms of some private and public bodies have convinced elements of the information market to sell it. An attempt at marketing acceptance is best typified by the rhetoric, assertions, and distortions from both sides, in the Proposition 15 campaign.

In absolute reality this form of acceptance may be purely fictional, but if properly packaged, it sells as the conventional wisdom and basis for public and private decisions.

It is often this mirage of acceptability which is offered as the push to motivate a transition from engineering acceptance to actual and widespread public acceptance. In reality, this thinly veiled form of Newspeak (recalling Orwell's totally marketed world of absolute thought and motivation control) and overpromotion that marketing acceptance evidences has contributed to, and perhaps initiated, some of the more agitated elements in the antinuclear movement.

To this point, the wonderlandish reasoning implicit in marketing acceptance, which pits alleged empiricism against intuition, has been less than convincing; indeed it has frightened those concerned and knowledgable about nuclear waste disposal.

PUBLIC ACCEPTANCE

Real public acceptance is characterized by the absence of hysteria and concern among the informed public and the key communicators who cue the acceptance or rejection of particular political and technical realities. It is a gross error (with consequent implications for interminable public dissent) to misperceive that public acceptability is the same as inferred engineering acceptance or its marketing extension.

The explanation for the lack of public acceptance of waste disposal evidenced in the public opinion polls to date seems self-evident. The invidiousness of any nuclear incident pervades public intuition--a subliminal replay of Hiroshima, Dr. Strangelove, and even Godzilla and other hyperventilating experiences of our childhood associated somehow with atmospheric testing of nuclear weapons. The modern fallout of this subconscious concern is a pervasive and desperate fear of a force which human senses cannot perceive and which (aside from cancer morbidity and mortality) is felt to produce irrevocable genetic alterations of an unknown magnitude. In an odd turnabout of marketing acceptance, our children who see Wizards are propagandized by a movie depicting an allegory of a future in which pollution and radiation produce a race of mutants which, under the leadership of the power of evil, attempts to eliminate the world of good.

Presently, the charge to alleviate and assuage these fears is being led by the engineers and technicians, who essentially will dish out assurances clothed in complicated mathematical models verifying the obvious.

Is it any wonder that the informed public lacks confidence? Is it any wonder that those who are typified as antinuclear zealots have their zealotry continually reinforced? Is it in any way possible to delude ourselves into believing the public isn't being dragged along in all of this, that "enhancing public acceptability" is anything but figuring out ways to appease troublemakers.

THE FEDERAL KALEIDOSCOPE

The political context within which the technicians are striving to "enhance public acceptability" is an incredulous collage of fancy (oft-times not so fancy) footwork, shifting the emphasis back and forth between surface retrievable storage to permanent waste disposal in a time frame which would have made the Apollo program shudder. Because of newly discovered concerns, haste and waste may be incompatible and that actually waste as historically conceived may never exist because of the relationship between reprocessing and weapons proliferation...the Energy Research and Development Administration (ERDA) withdrew its witnesses scheduled for our hearings last week, noting they didn't know what shift in policies or programs would be necessitated until after 20 April. The President's policy now apparently disallows reprocessing, effectively introducing a real wild card into whatever permanent waste disposal efforts had accomplished.

Yet we today will be discussing a background paper on public acceptability which contains the assertion that "high-level and transuranic waste can be irretrievably disposed of by state-of-the-art methodology...." I find it doubtful that even a conscious effort could be more successful at arousing the informed public. Whether or not the statement reflects reality is of little relevance--the way to public acceptance simply does not start by direct assault on intellect.

A PERCEPTION OF TRANSITION PREREQUISITES

Having observed the general nuclear, and specifically the waste disposal, controversy closely for a number of years, in both a state legislature and regulatory agency milieu, I would suggest that there are several prerequisites to any transition from public anxiety and suspicion to a state of greater government credibility and confidence. I will briefly mention them here, in hope that they will be debated in succeeding Workshop days.

First, the assumptions underlying this and all other discussions of public acceptance must undergo radical alteration. I believe the biggest impediment to public (or at least surrogated public) acceptability is the fundamental difference between solving problems in stream as the technology proliferates compared with slowing or stopping deployment until acceptable technology is demonstrated. In the case of waste, we have the ultimate anomaly, which is that our demonstration would have to run hundreds of years to be even statistically validated.

In the absence of such "tests," we instead have created our own cult of devil's advocates who just like their historical ancestors are employed by the institutions which they are supposed to check. Russell Train, former EPA Administrator, protests the deployment of nuclear power within months of leaving office. What does he know or feel that we do not? The thought that we can't or perhaps shouldn't continue to count on as rapid deployment of the technology as anticipated in the face of a series of apparent imponderables is nowhere to be seen in EPA background papers or prior Workshop results.

Where is the dissent, the skepticism of technology and its advocates that one sees in the courts, both in the United States and West Germany?

It is not that the engineering argument should not endure, but that it must be argued, explained, and be part of the debate, not a preordained nostrum.

It is possible that the radioactive waste system may be on the same learning curve as was LWR technology: first, infallibility asserted; then, worst-case assumptive planning; then, court-ordered release of such worst-case plans; and finally, bureaucratic response by, in theory, complete and competent analysis. All the while, however, this technology is embroiled in controversy as to whether certain integral safety systems could be hypothecated to work while admitting they would never be fully tested. Additionally, certain events were not ruled as low-probability events, but were asserted to be incredible--not even worthy of analysis.

In waste we have an even more sanguine state of affairs, the worst aspect of which is the constant assertion by many, on the one hand, that institutional mechanisms to set policy let alone hardware do not exist, and on the other, that the technology already exists and merely requires political courage to implement.

Such polarization takes place in an atmosphere where waste management has been an admitted stepchild, with little or no work being done on it in the recent past, and as of 7 April, the work that has been done may be substantially moot.

It is my belief that in light of these gross uncertainties and disputes, public acceptance, as distinguished from legal, technical, or marketing acceptance, will not be forthcoming until we admit that the problem is potentially serious enough to disallow further waste generation until such time as we verify our engineering theory.

Second, I believe any transition to acceptability entails refraining from the misdirected numerical gymnastics which pit alleged empiricism against informed intuition. The cardinal examples which come to mind include:

1. Carefully unqualified comparisons of the relative toxicities of high-level waste vis-a-vis naturally occurring uranium ore; comparisons which are not done on a per unit mass basis (Ref. 2) (which is what toxicity is all about) or which often compute the toxicity of wastes on a volume basis by averaging over the volume of the entire salt mine in which the waste is emplaced (Ref. 3). This is extremely important because it sets the bounds of the institutional stability necessitated for safe sequestering, 1,000 years being inestimably different than 250,000.
2. Apparently Rasmussen is to be revisited, most certainly to produce absolute estimates of probability (based on some statistically significant failure rates somehow obtained for a system which has never existed), numbers which, if history is any guide, will find their way into comparisons with observed actuarial risks.
3. Continued comparisons of projected possible releases with observed natural levels of radiation. While this is, at first glance, appealing, it may have no absolute importance. We don't know what ambient background radiation is doing to us, as Dr. Ida Hoos, an Ames researcher, has pointed out. These comparisons are of course supplemented by the no-news-is-good-news mentality--"if you can't prove that a whole bunch of cancers took place,

then goody (Ref. 4); it's safe to escalate deployment exponentially...; "What you can't count won't hurt you...."

A third prerequisite is an objective analysis of the 1985 demonstration. In a millennial process, why the rush? Why the crash determination of goals? What will it prove or resolve, as Willrich aptly points out, beyond our ability to receive and emplant waste? It seems to me these things will not be overlooked by the informed public. What shortcuts are being taken to what end? Can EPA, apparently underfunded, finesse an adequate job in less than a year? Why should they? Is "adequacy" acceptable? Should we, in this instance, take the time for more?

I would like to conclude with a final point which is fundamental to this Workshop and, I believe, the most important and fundamental aspect of the public acceptance question. My preceding discussion distinguished three kinds of acceptability: engineering, marketing, and public; I have also indicated the importance of not blurring reality so that one believes that an industry or parabureaucratic acceptance mirrors public acceptance.

My perception of what is happening here (and happened in Reston), of what the real output will be, is a struggle for control, the winner of which will be allowed to define reality, the important reality in this instance being the definition of "public." If I may, I refer you to the background paper on public acceptance prepared for this Workshop: "The public, for the purposes of this paper, comprises those individuals not affiliated with the regulatory authority for the purposes of the development and issuance of these criteria and standards."

While the devastating implications of this statement may be apparent, I would like to share with you my perceptions of them. Quite simply, this definition which generously includes everybody, if accepted, will of itself guarantee that we will be unable to gain true public acceptance. Clearly, it is ludicrous to suggest the public includes the regulatees who, relative to the true public have essentially infinite resources for affecting outcomes. The system is thus certain to be overwhelmed; the outcome the regulatees desire will evolve, with the public, as usual, left in the dust. In my view, this represents the antithesis of a sincere effort to gain public acceptance, and I suggest to you a definitional change is the appropriate first order of business. Of course, the regulatees have an important and perhaps crucial role to play, but that role is to advocate and convince the public through processes such as you have established here. Then the public acceptance will not be "enhanced" but in fact be knowingly given.

Since we may have defined public acceptance indirectly by saying what it is not, let me close by qualifying the criteria set out above:

1. Tell the public the whole complicated truth--up-front.
2. Reduce mental reservations to the fullest extent possible when producing evidence or hard facts about the nature of the issues.
3. Challenge and analyze technical assertions which alter the quantum nature of the debate by orders of magnitude.
4. Conduct up-front worst-case analysis. If the material gets out, how bad will it be? What will be the pecuniary and social costs?
5. If we are making trade-offs of both a quantifiable and nonquantifiable nature, as well as various unknowns, be explicit.

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PUBLIC ACCEPTANCE OF RADIOACTIVE WASTES DISPOSAL: AN ARCHAEOLOGIST'S PERSPECTIVE

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One of the most crucial elements in public acceptance of risk from radioactive wastes disposal is public perceptions. At this time, public mythologies are in flux. In our society's "old mythology," technology was our saviour and solution whatever the problem. In a "new mythology," bred of energy crises, mountains of solid waste, and environmental disasters, technology often is the problem (Ref. 7, 8, and Issues and Objectives paper for this topic.) The new solutions, therefore, must focus on the attitudes, decisions, and resulting behaviors which control technology and which create and discard material culture.

Although this paper is only the opinion of one individual, the ideas presented below do benefit from the specific perspectives of archaeology--the study of our cultural heritage. In this discipline, the rise and fall of past civilizations is reconstructed from their material remnants. This perspective focuses on ancient artifacts and structures which are now detached from human behavior. Perhaps because past human attitudes and actions are retrieved only at great pains, archaeologists are very sensitive to the dynamic relation between human behavior and material items today.

At a basic mechanical level, an archaeological perspective is important in assessing sites for the disposal of radioactive wastes. The suitability and significance of particular regions is evaluated in terms of the nature and distribution of irreplaceable cultural resources--the material heritage left by our ancestors. Four types of significance must be considered:

1. Research significance: the relevance of cultural resources for answering questions about events in the past and validating general models of cultural process;
2. Public significance: the educational and aesthetic value of cultural resources as foci of public tourism and/or recreation (with attendant benefits to local economies);
3. Ethnic significance: the religious, mythological, social, or other symbolic importance of cultural resources for a discrete population;

4. Historic significance: often a combination of the first three, the relation of cultural resources to specific "historic" persons and/or events (Ref. 9, 3). In projects with Federal involvement which may threaten the destruction of cultural resources with scientific and symbolic value, the National Environmental Policy Act of 1969 requires that the effects of proposed actions be taken into account in the planning process (Ref. 6). Thus, a full archaeological evaluation of disposal sites would be necessary.

Any kind of thorough site evaluation, especially in the case of radioactive wastes with long-term risk, would have to add another dimension--likely future significance. Much of this would be beyond an archaeologist's expertise, but some contributions could be made.

From his long-term perspective, an archaeologist could partially evaluate potential future utilization based on the history of past utilization. From the time the Spanish entered the New World until the last decade, the Peten was a vast expanse of rainforest nearly devoid of human population. Now, however, a new road from Guatemala City is bringing settlers to the area in large numbers. This new settlement pattern is no surprise to archaeologists. The same rain forest was the heart of the Classic Maya civilization from around 1000 B.C. to A.D. 850 (cf. Culbert 1973). In other areas, archaeologists have predicted future exploitation of "wastelands." Evenari (Ref. 2) has experimented with the remains of a complex agricultural system in the inhospitable Negev. The remnants date to the Byzantine Period, but have been demonstrated to be capable of efficient production at present, 1,300 years after their last sustained utilization. Thus, specific educated guesses about future human behavior in an area may prove useful.

Another kind of contribution can be made at a more general level of discussion; the following comments have a broader relevance because they are based on general patterns of behavior within the discipline of archaeology and within the development of past civilizations.

The option of "concealment" of radioactive wastes has been mentioned in the Issues and Objectives paper for this topic. From an archaeologist's point of view, this is neither practical nor ethical.

One hundred years ago it was not possible to predict the techniques archaeologists are using today. It is just as impossible to predict the techniques archaelogists will use in 100 or 200 years from now. But what they will look for is certain. Archaeologists are trained and mandated to search out man-made anomalies--to recover all possible data on the past activities of humans which are not already recorded. We also do not know where archaeologists will look, but since humans have occupied almost every part of the world at one time or another, there are few boundaries. Thus, it is likely that archaeologists of the future might find concealed radioactive wastes.

It has been argued that if the wastes were buried 1,000 ft below the present surface, discovery would be unlikely. However, archaeologists already use an extremely sophisticated repertoire of technology in their explorations, and many new devices are on the way. For example, to bury wastes, the surface must be disturbed. Remote sensing aerial photography and thorough survey on foot--techniques in use today--would probably detect this activity. Another need of archaeology, paleontology, and geology, makes discovery likely. The vast majority of the data these disciplines seek to study are buried and leave no visible clues on the surface. Therefore, there is an obvious utility for technology to discover and describe certain types of deeply buried anomalies. Already, archaeologists are using proton magnetometers (Ref. 5) and other devices which portend more effective mapping in the future.

A second argument is that anyone sophisticated enough to find the disposal site would know the dangers involved. This is a supposition. It may be correct. However, it may also be that future archaeologists will not be prepared for the risks involved. In addition, looters, prospectors, and other types of independent explorers are always interested in human-made anomalies. In fact, as a general rule, they usually beat archaeologists to them. They utilize crude, but effective, shortcuts and would probably not be at all prepared for what they found.

This may seem a set of rather silly suppositions on my part. Anything buried 1,000 ft below the surface would surely be safely kept. First, because it would be well concealed; secondly, because the technology necessary to reach it--in our day and age--could only be mustered by large and responsible organizations. But the history of archaeology might make us think again.

The ancient Egyptians had commodities they too wanted to protect from discovery and removal. During the Old Kingdom (around 3000 to 2400 B.C.) a tremendous share of the Egyptian gross national product was invested in the three pyramids of Gaza and thirty other similar structures. In addition to a marshalling of almost their full means of production, some pyramid tombs had devices--the most ingenious and sophisticated of their day--to foil desecration and preserve their contents. Nevertheless, when Belzoni and other infamous 19th-century plunderers used battering rams and other techniques to break into the central chambers of the great pyramids, they entered barren rooms stripped of their prizes (Ref. 1).

Later Pharoahs of Egypt determined that concealment should be added to their strategies, but it does not seem to have been significantly more effective. Of the forty tombs of Pharoahs located by archaeologists in the cliffs of the Valley of the Kings, only one was found intact during our modern era--the tomb of Tutankhamen, opened in 1922. All the rest were plundered to one degree or another in antiquity.

The message of the Egyptians seems to be that what is safely concealed by one society may be easy pickings 10, 100, or 1,000 years later. From the experience of archaeologist, then, concealment is a proposition with attached risks.

But what if concealment is complete? What if nobody on the trail of past behavior discovers the site? Is it safe? The answer is probably not. This type of situation could be even more dangerous than intentional discovery.

We know that any disposal site will most likely be a desolate area, far from large habitation and work areas--a wasteland for humans. The only problem is that if we consider our past development, one clear pattern has been a continual redefinition of useable resources and a continual expansion of our working and living activities into formerly marginal geographic areas in pursuit of formerly marginal commodities. Only a few decades ago oil was a nuisance. Only a few years ago uranium was of no consequence. Today, explorers venture into virtually untouched areas--deserts, sea coasts--to drill and mine these resources. It is certainly possible that disposal sites may become the focus of new resource definitions. The unexpected discovery of concealed radioactive wastes would, at the least, be an extremely unpleasant surprise.

The advantages of concealment must be carefully weighed against the prospect of almost certain intentional or unintentional discovery in the future.

In the Issues and Objectives paper for this topic, there is a clear premise that a technological solution for radioactive wastes disposal will be found in the future. It is true that in the past, technological solutions for many problems have been found. It is also true that from a general perspective, technology has continued to develop in utility and sophistication. Often however, technology generates problems--as in the case of the radioactive wastes we are discussing--and, often, solutions are found too late for specific civilizations. Cultural and technological development march on, but sometimes they leave individual civilizations behind.

For example, in the early Near East, McGuire Gibson describes a case of "engineered disaster" in the application of technology (Ref. 4). For many early civilizations, complex state-run irrigation systems provided a solution to feeding growing populations and supporting expanding production and trade systems.

However, large-scale centralized irrigation systems bypassed local autonomy, cut local fallow cycles, and led to a rapid increase in soil salinization. As productivity decreased, the system did not revert to old fallow patterns. In fact, to minimize immediate losses, a short-sighted strategy was followed--fallow cycles were cut further. The result was a rapid increase in the rate at which the whole system became unworkable and the cities and their irrigation networks were literally abandoned.

The point is that solutions often create problems themselves. Therefore, I believe that our most rational course is to base our proposed radioactive wastes procedures on the technology presently available. Rational decisions based on current knowledge may help to avoid unforeseen future disasters.

Once sites are evaluated in short-term and long-term perspective and once trade-offs have been analyzed, the public, both at the site and in general, must accept the resulting decisions. This may not be a response which is easily obtained. This type of problem is shared by archaeologists.

The scientific, educational, aesthetic, and symbolic value of our past cultural resources and their preservation is usually clear to the general public. Nevertheless, in local areas throughout the world, archaeologists often run into resistance in evaluating them and preserving them. The local difficulties stem from two basic sources. Often sites to be surveyed or excavated have a local religious or symbolic significance which is damged by exhumation, analysis, and removal. For example, Native American populations are disturbed by excavation of the burials of their ancestors and removal of artifacts with religious values for study and display. Other sites to be studied and protected have economic significance. Preserving a site takes it out of the realm of financial exploitation by local looters and can substantially decrease their revenues.

The lesson learned here by archaeologists is that there is no set risk compensation factor that can be appied to all situations and that the activities of archaeologists cannot be concealed. Archaeologists have succeeded in dealing effectively with these problems where they have had free and open talks with affected populations. Thus, rather than concentrate on outlining risk compensation factors, these Workshops might profitably consider guidelines to open and regulate the process by which concerned parties interact. Archaeologists have found by experience that the result of open discussions--concerning both local risks and general benefits--is usually a working relationship which is surprisingly acceptable to both parties.

In this process it seems likely that the feeling of local worth, generated from consultation at all phases of planning, leads to the development of an increased ability to bear the responsibility of risk. It is one thing to have risk literally dumped on you by the general public--where you function as the scapegoat; it is an entirely different matter to make a decision to shoulder responsibility for the good of the general public. The perceived weight of the loads might well be significantly different.

My final comment may go beyond the concerns of this Workshop, but it relates to an archaeologist's concern for long-term perspectives. The point at which all of the above considerations must be weighed is not after the risk materials have been generated. One problem with accepting radioactive wastes is that they are the result of decisions often made without these final disposal decisions in mind. This may be a burden which is hard to bear for disposal site populations. The long-term disposal problems should form a crucial part of the decisions to expand the use of nuclear power; and disposal site populations should have a part in the initial phases of this decision process.

Public acceptance of radioactive wastes risks depends on a clear understanding of what trade-offs are involved in the use of nuclear power. The public's new view of technology as fallible is not necessarily cynical, but it is realistic. To achieve public acceptance, the benefits and risks of nuclear power must be presented in an equally realistic manner.

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PUBLIC ACCEPTABILITY OF RISK FROM RADIOACTIVE WASTE

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Frankly, I don't envy you either in the task of determining what are acceptable risks from the public's point of view, or in the task of affecting or achieving public acceptance of those risks. You have a very tough problem and I am not at all sure I can help you with it.

There are a variety of problems in ascertaining and achieving public acceptance, but let me start with just one of them, which is the public's present attitudes towards the problem. In January of this year we gave people a list of nine problems and asked them to tell us each one they thought represented a "serious threat to future generations." The number one perceived problem of the nine we asked about was "more and more nations developing the capability to conduct atomic warfare." Of the nine problems, this was cited by 49 percent of the adult American public as a serious threat for future generations. This does not, of course, have anything to do directly with disposal of atomic wastes, but it indicates the wariness people have about "atomery" in general.

In fourth place of the nine problems asked about was "the radiation problems that will be caused by the increasing amounts of atomic wastes that must be disposed of from atomic plants." While this item ranked fourth as a threat to future generations, that makes it sound less significant than it is, for it was cited by 41 percent of the public, which is not many less than cited the proliferation of atomic weapons. To give some perspective, the atomic waste radiation problem was cited by 41 percent, whereas the increasingly widening gap between developed and underdeveloped nations was cited by only 17 percent and the prospect of increasing numbers of devastating earthquakes was cited by only 16 percent.

Further evidence of the public's atomic concerns comes from another question we have asked every fall for the last four years. This question has asked people whether they feel that an atomic energy plant "someplace near here" would probably be safe or would present dangers and hazards. Every time we have asked this question, more have cited dangers than have thought such a plant would be safe. Moreover, last fall the smallest percentage in any of the four years said safe, 33 percent, and the largest percentage in any of the four years said dangerous, 46 percent. Thus, on balance, the public is concerned and is becoming increasingly concerned.

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It is against this backdrop that you will have to seek public acceptance of the risks of atomic waste disposal.

It seems clear to me that a necessary prerequisite to gaining acceptance of some level of risks is to make people aware of the seriousness of the energy problem that exists in the world, and specifically in this country which relies so heavily on energy. Nobody is going to accept any level of risks purely for the sake of appearing fearless. People will only accept risks if they have the clear understanding that the alternatives to those risks are even more unacceptable. Let me, therefore, take a minute to outline briefly what the public's perceptions are of the seriousness of the energy problem. In May of 1974, shortly after the gasoline crisis and gasoline lines had ended, we asked a national sample of adults to tell us which of four statements best described their opinion of the gasoline and oil shortage. Twenty-one percent subscribed to the most serious of the four statements, "There is a very real oil shortage and the problem will get worse during the next five to ten years." By contrast, 53 percent opted for the non-problem statement, "There never was any real oil shortage--it was contrived for economic and political reasons." Against that kind of perception of the problem, people are not likely to accept any considerable level of risks.

But that, of course, was nearly three years ago and a lot has happened in the interim. We have repeated this question several times since early 1974, our last asking being November of last year. Not surprisingly, there is an improved understanding of the seriousness of the oil shortage. The percentage who subscribe to the most serious view that we presented them is up from 21 percent to 26 percent. The percentage who see the oil shortage as a non-problem is down from 53 percent to 46 percent. Nevertheless, while this represents progress, it still means that nearly twice as many see the oil shortage as a non-problem as see it as a serious problem. To put it another way, as of last fall only one out of four saw it as a real shortage that would get worse in the next five to ten years.

At the same time, there is obvious ambivalence about the fuel shortage. This January when we gave people a list of some dozen problems and asked them to tell us which two or three they were most personally concerned about, the fuel and energy crisis came in third, which was high on the list. On the other hand, it was only named by 31 percent and was well behind both inflation and crime as public concerns. At the same time, another question, asked only a month earlier, suggests that people do sense an energy problem even if they refuse to recognize the immediacy of its potential impact. When we asked people whether they felt the nation was spending too much, too little, or about the right amount on each of a dozen problems or programs, the overwhelming balance of opinion was that we were spending too little on increasing the nation's energy supply. Of the dozen items asked about, there was only one other on which a higher percentage of people felt we were spending too little and that was on halting the rising crime rate.

Another evidence of the ambivalence that exists in this whole energy area comes from another question we have asked repeatedly since the fall of 1973. This question posed the possibility of a crunch or conflict between having adequate energy and protecting the environment and asked people which side they would come down on if they have to choose between insuring adequate energy and protecting the environment. The results have flipped-flopped as the energy situation has changed. For example, in January of 1974, at the height of the gas lines, people came down on the side of insuring adequate energy by a four to three ratio. As of last fall, the ratio was exactly reversed, four to three in favor of environment. I might mention that those are the extremes we have gotten in the seven measurements we have made. More important to me than the flip-flops is that there is strong concern about protecting the environment while solving whatever energy problem we may have. Undoubtedly, if there were a greater perception of the seriousness of the energy problem, people would be willing to take somewhat greater risks with respect to the environment. But it is clear that the environment is a strong consideration in people's thinking.

So I think the first requisite for getting people to accept risks is making them aware of how serious our energy situation is. In that connection and in support of that contention, let me tell you the results of a question we have asked about how we should conserve or increase our energy supplies. We have given people a number of options and for each one asked whether it is something we should or should not do. We have asked the question several times in the last three years. This February, however, we changed the introduction to the question. Instead of talking vaguely about the undefined fuel and energy problem in this country, we introduced the question by pointing out that we are now importing 40 percent of the oil we use and that the rate is increasing. We also pointed out that the supplies cannot last forever and that the experts say we have to find ways of both conserving and developing new energy sources. Against the background of urgency, the percentage saying we should increase offshore oil exploration jumped from 61 percent to 79 percent in eight months. The percentage saying that we should have a greatly expanded atomic energy program jumped from 47 percent to 61 percent and the percentage saying that we should allow more strip mining of coal jumped from 42 percent to 57 percent. This seems to me to document the fact that an understanding of the seriousness of our energy situation is a prerequisite to getting people to realistically assess and accept risks of all kinds, including the risks of atomic waste disposal.

The second thing I think that has to be done is to make people aware of what all the risks and benefits are--what the trade-offs are. Obviously, this cannot be too technical, for there is a limit to people's abilities to absorb technical information. And that, of course, is one of your problems--how to make people properly informed without getting too technical. But there is another problem also, although it is substantially easier to deal with. I think it is absolutely essential, in educating people to the risks and the benefits, to accurately inform them as to the full impact of the risks as well as the benefits. In the last few years, for a variety of reasons, the public has become extremely cynical and skeptical. To achieve credibility, it is crucial that you tell it like it is and reveal the warts as well as the beauty spots. When President Carter on several occasions said he didn't know on his call-in radio program, I am sure he enhanced his credibility significantly.

My third suggestion--and here comes the commercial message--is to conduct polls or surveys that will both assess people's knowledge or lack of knowledge about the risks and benefits of atomic energy and the waste disposal problem and also their attitudes towards these risks and benefits. I suggest such polls for two reasons. I don't think you should be blinded in your deliberations by organized pressure groups that can, by their pressure and vocal nature, create the illusion of speaking for the public at large. Moreover, such polls can help you in justifying the standards you establish and can help you in refuting the contentions of pressure groups. But in saying this, I think it is crucial that the polls not be designed to justify pre-determined actions on your part, or to refute charges of pressure groups. Just as I said a moment ago that I think it is essential that you tell it like it is, I think it is also essential that you measure it like it is.

I would also suggest that the polls be continuing so that trends and changes be observed. Moreover, I would warn you against being lulled into a false sense of security by poll results that are obtained before the fight is joined. For example, shortly before the New York and New Jersey votes on state equal rights amendments (ERA), we conducted a national study that showed the public overwhelmingly in favor of ERA. Moreover, the northeastern section of the country was one of the areas most strongly in favor of ERA. Yet ERA failed in both New York and New Jersey, which caused some to be skeptical of our poll. A month after the defeat, we repeated the same question and again we got overwhelming support for ERA--and, specifically in the Northeast, a very large part of which is accounted for by New York and New Jersey. This may mean that our poll was wrong a second time, but that isn't the meaning I draw from it. My conclusion is that a small organized group that feels strongly on an issue can make its influence felt during a heated and emotional campaign where the majority of the public may have a contrary view, but also feels comparatively apathetic. From the furor that the anti-abortionists created during last year's primaries, one would assume it was an issue of major national concern. It wasn't, except to the comparative handful who felt so strongly about it.

If the public has some Solomon-like decisions to make with respect to trade-offs, benefits, and risks, it seems to me that you do, too. One of them is how much weight to give to the highly informed and those who feel passionately about the subject versus the less informed and more apathetic. After 30 years in this business, I am convinced of the inherent collective wisdom of the American public, given reasonable information on their part. The problem for you is to decide what is reasonable information. Reasonable information by no means equates with maximum information. On the other hand, it doesn't equate with minimum information either. In the same vein, another problem for you is how much weight to give those who will be immediately affected in terms of proximity to atomic waste disposal versus the much larger group who will be less personally affected and may, therefore, have quite different opinions. While I recognize these problems, I'm afraid I can't be of much help to you in resolving them.

Let me close on a somewhat brighter note. You do have some things going for you. I mentioned that the public was ambivalent about the energy problem. There are favorable aspects of that ambivalence. For example, a year ago we asked people for each of six problems, whether they thought it was something their Congressman should give major attention to or whether there were other more serious problems that he should devote his energies to. The number one problem that people would like to see their Congressman address is tax reform, cited by 75 percent of the public. However, very close behind it and well ahead of such things as national health insurance or regulation concerning the transport of toxic chemicals or programs to hire the unemployed in government jobs was the development of a national energy policy, considered a proper target of their Congressman's energy by 74 percent. And that was a year ago, before the heavy recent focus on a national energy policy. Secondly, you will be pleased to know in general terms, but specifically in terms of the credibility problem you face, that there has been a very sharp jump in the last several months in people's favorable attitudes towards government and political leaders. Our latest study shows jumps of 10, 15, and 20 percentage points in people making favorable characterizations about government officials and similar drops in those making unfavorable characterizations. Part of this is due, I am sure, to the new Carter administration. But part of it is also due to the fact that the public is showing a general ebullience and optimism about life in general. The economic outlook is brighter, Vietnam and Watergate are behind us, and in an atmosphere of feeling good in general, there will be less skepticism and cynicism about institutions and programs of all types. Also, I think that the forthcoming comprehensive energy policy about to be proposed by the Carter administration should help in two respects. It should make people increasingly aware of the seriousness of the energy problem and, in addition, by dealing with all kinds of energy and all the trade-offs involved, it should help to put the risks of atomic waste disposal in the context of other risks and other sacrifices.

Finally, I think you may be encouraged by some results that just came off the computer yesterday morning. Last month we pointed out to people that certain kinds of decisions are voted on by the public and other kinds of decisions are made by various kinds of expert bodies--for example, air safety regulations are made by the CAB, not voted on by the public. We then asked people whether each of six kinds of decisions were best made by the public or by some kind of expert group. A majority thought the public was best qualified to determine who shuld be judges, and what should be taught in the public schools. On each of the other four, however, people thought expert groups should be the arbiters. The four were: where atomic plants should be built (49-40), what speed limits should be (58-36), what safety features should be required in cars (61-32), and, most importantly from your point of view, how atomic wastes should be disposed of, which had the biggest margin of all in favor of decision by expert groups--64 to 24 percent.

But, while this may be comforting, it clearly also places on you a heavy responsibility to determine public concerns and fears and to take them into account in your decisions.

I think I see your problem fairly clearly. I only wish that I could provide you with more answers to that problem.

PUBLIC ACCEPTABILITY OF RISK OF RADIOACTIVE WASTE DISPOSAL

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The opportunity today to formally present a "public interest" viewpoint on the disposal of radioactive wastes is most welcome and hopefully a sign of a longterm change in attitude in the country and government. Clearly though, what I say today does not necessarily represent the precise view of every public interest group. What I say represents one group's effort to suggest answers to problems about which many such groups and many others in the general public share similar concerns.

The third topic for the Workshop today, "Public Acceptance of the (known or perceived) Risk Associated with Radioactive Wastes," at first reading suggests that we are discussing how to develop criteria and standards for radwaste handling and disposal so that the general public will find the residual risks resulting from the whole process acceptable. Indeed the Issues and Objectives paper prepared by the Environmental Protection Agency (EPA), in large part, discusses public acceptance as referring to the general public. As the note on the first page of this paper makes explicit, however, the public is everyone except the developers of the criteria and standards. Thus we are also discussing the nuclear industry's concrete acceptance of the reality of the risks and the general public's legitimate concerns about them in the form of open and effective efforts to reduce the risks to a minimum.

Indeed, the necessity for legally enforced criteria and standards arises mainly out of the apparent reluctance of the industry to handle its wastes in a manner that evidently and effectively minimizes the risks to its workers and the general public. This reluctance is not pure obstinacy on the industry's part, since other industries have not been required in the past to do this, the costs are not clear, and the competitive edge of the industry may be dulled. Yet it is open and cooperative acceptance by industry of enforced criteria and standards that will go a long way to convince the general public to accept the residual risk associated with properly disposed wastes.

What I have just said is not merely a recital of a rationale for legal criteria. It is meant to suggest that in addition to technical criteria for effective waste disposal, we need criteria for the process of developing satisfactory disposal methods. The general public will be more inclined to accept the residual risks of radioactive wastes if the process of developing the disposal methods makes clear that the industry accepts the responsibility for creating the wastes and risks and creatively cooperates in reducing the risks to a minimum.

The need for criteria for the process of developing disposal methods as a means of encouraging public acceptance of the risidual risks arises from the total situation in which we find ourselves today. We have on our hands large quantities of radwastes from weapons production. We have committed ourselves to the wastes produced or to be produced from some hundred commercial reactors, since the large financial investment and the existing dependence on their generating capacity makes it very unlikely they will be shut down. The general public wants clean air and pure water, and finds it hard to believe that the scientific and business community which produced the beautifully engineered machines cannot also manage the wastes so as to assure a safe environment. Yet some 15 to 20 years after the admitted need for safe disposal produced a government and industrial program to develop disposal sites and methods, we find ourselves starting almost from scratch on new programs. But we have learned that we don't know all we need to know, that finding suitable sites is not all that simple, that effective containment on site is not as easy as we hoped, and the general public has a legitimate and growing interest in a sound program. The current program to develop disposal sites and methods has become an experiment, the success of which is a requirement for long-term reliance on nuclear power.

The criteria that we need now are then experimental criteria. The technical criteria established now must be experimental; actual experience in handling limited quantities of wastes in the chosen disposal sites will determine the adequacy and feasibility of these criteria. For example, current estimates of biological hazard suggest that near zero release be the goal of the total disposal program. For a delimited quantity of wastes at a given experimental site, a criterion of as low as reasonably achievable (ALARA) might be the operative rule. In the process of developing the chosen site and methodology, the question to be answered is how close to the goal the ALARA criterion brings us. If the discrepancy is large, the experiment would be terminated and corrected; if not, the delimited quantity could be fully disposed of by that technology. The guiding philosophy would be that the delimited quantity is better disposed of than not disposed of, and that it is preferable for planning, cost control, and full extraction of information to complete the experiment. Part of the experiment would be a period of time after disposal is complete to monitor the success of containment for the limited waste quantity. Expanded use of the site and methods would depend on success of the whole process.

The process I have been outlining clearly requires at least three types of criteria:

1. The operative criteria for each delimited experiment;
2. Criteria for comparing each experiment with the overall goal, for determining the need for termination or suitability for continuing the experiment to completion, and for determining the operative criteria for each successive experiment;
3. Criteria for matching progress of the waste disposal programs against the introduction of new sources of wastes. This last criterion is necessary to prevent a continuing uncontrolled accumulation of wastes that would negate the experimental character of the disposal program. Without control over the production of the wastes in step with the progress of the disposal program, any effort to apply criteria and standards will collapse under the pressure of managing an impossible situation.

Clearly this last type of criterion--controlling growth of the wastes by the progress of the disposal program--takes the current effort to develop criteria and standards into the general arena of the risks/benefits of nuclear power. But this is unavoidable, in my opinion, since public acceptance of the risk of radioactive wastes both by industry and by the general public clearly depends on the perceived necessity of accepting the risks. It is clear that existing wastes and those from existing sources must be adequately disposed of--the risks exist and hopefully can be diminished by a good disposal program. The program is experimental with relation to estimating the risks and costs of additional wastes and is part of the evaluation of the net contribution of nuclear power to human welfare.

This program of radwaste disposal as an ongoing experiment has a number of advantages both for the industry and the general public, and some disadvantages for both. The nuclear utilities will be assured that at least part of their wastes are disposed of, easing the buildup in storage facilities. The general public will be happier that some of the wastes are being better handled than they are now and that a planned program is in progress. In addition, because the wastes in each experiment are limited, failure of the experiment will result in limited risk at any one site. The disadvantage is that the local population must accept the possibility of failure of the local experiment. The disadvantage to the nuclear industry is that it does not allow a full go-ahead for the nuclear manufacturers at this time, but the program would contribute to resolving the question about nuclear power's role in the long-term energy picture.

In summary, current knowledge and experience do not allow establishing permanent technical criteria and standards for radwaste disposal at this time. Public acceptance of the risks is not therefore assured by the technical criteria set now. Public acceptance will depend, therefore, on the evident suitability and reasonableness of the criteria for the process of managing the experimental disposal programs.

Some more specific questions raised in the Issues and Objectives paper can be answered within the above framework. Criteria for managing the various experiments and for additional waste production, as well as the near zero release goal, could be common to all radwaste types. The operative criteria, however, could vary to take account of the differences in waste characteristics. Accidents and unplanned events might not be covered by the operative criteria, but would be a determining factor under the process criteria in evaluating the success of a given experiment. Process criteria would determine the amount of waste allowed at an experimental site, determining the limit on risk to the local population. A contingency insurance pool to pay for correcting unplanned releases or for safely terminating a failed experiment, including costs of transfer to another experimental site, would be necessary. Record keeping and monitoring would be part of the operative criteria, with the process criteria perhaps requiring ultimate destruction of the records and monitoring stations after successful completion of an experiment or adequate succession of experiments.

A final word about the public review process for the Waste Environmental Standards Program. The review and public hearings approach does not in general do justice for the need for mutual understanding between drafters of the criteria and the public. Much more give-and-take on concepts and decisions made is required to make objections clear to the drafters and to explain the rationale for the criteria to the public. This difficulty is easily overcome by industry lobbyists, but not so easily by the general public. Perhaps a Workshop or similar forum where the EPA is not an observer and data gatherer, but an active explainer and defender of its criteria and their rationale could overcome the weakness of the formal review procedures.

PUBLIC ACCEPTABILITY OF THE RISK ASSOCIATED WITH RADIOACTIVE WASTE: SUMMARY AND CONCLUSIONS OF WORKING GROUP 3

INTRODUCTION

Working Group 3 was composed of approximately 50 participants. In addition to a number of unaffiliated citizens, the working group consisted of representatives of diverse organizations, including government agencies, environmental and energy action groups, industry, mass media, universities, and research organizations.

The group initially attempted to address the 11 questions posed in the Summary of Considerations section for Topic 3 in the Issues and Objectives Statements document that was distributed prior to the Workshop. During the working sessions, however, this list was shortened and modified to include the questions treated in the following subsections.

In the paragraphs that follow, it should be clear that the statements represent a consensus only where it is clearly stated that one existed.

WHAT DO WE MEAN BY PUBLIC ACCEPTABILITY OF NUCLEAR WASTE MANAGEMENT CRITERIA?

The panel did not come to a consensus on the question but acknowledged that there are multidimensional factors associated with answering the question. It was noted that public unacceptability is easier to define and measure than public acceptability.

In this context the working group understood the term public to mean (slightly modified from the Issues and Objectives Statement) the following:

> The public are all members of the U.S. society who are not those Federal officials promulgating nuclear waste management criteria.

The definition of the term "acceptable" was considered. Although not agreed upon, the vague definition of "Webster" was offered:

> An item is "acceptable" if it is capable or worthy of being regarded as proper, normal, or inevitable.

Many factors associated with answering this question were considered. Some of these were:

1. How important is the level of knowledge in considering the opinion of members of the public?

2. What is the proper way to balance the attitude of members of the public near a potential waste management site with those of the national public?
3. Public attitudes and expressions of acceptability change over the course of time. In what way should these unpredictable changes be adequately considered in the development of the criteria.
4. Is the attitude of a majority of the public at large, as measured in opinion polls, important to the determination of public acceptability? Is positive approval by a majority of elected officials important or necessary?
5. At any one point in time, acceptability of the criteria is dependent upon a wide spectrum of societal value judgments. Agreement with these value judgments is probably achievable only on a gray basis.

Some of the characteristics which may affect acceptability were also considered. Among these were:

1. Defensibility, which is a function of "reasonableness," identification of logic used, and the traceability of logic.
2. The language used in the criteria and the defense of the logic must be presented in simple, succinct language and be well documented.
3. The criteria should be practical to achieve, that is, they should be associated with technological alternatives.
4. In order to be useful, a criterion or a standard should be enforceable.
5. The greater the benefit to society in implementing a criterion, the more acceptability it will have.
6. The risks, costs, and benefits should be presented in terms of many indices associated with the public's values.
7. Due to the time-dependent nature of acceptability and knowledge, the criteria should have a built-in review and modification process. However, the criteria should be as durable as possible.

Some participants thought that the degree of public acceptability will be enhanced if the attendant risks/benefits are comparable to existing accustomed hazards (including man-induced and natural or "background" hazards).

Another view was held that acceptability of developed criteria is linked to public perception on the development of nuclear energy and the Federal government's role in that development. It was agreed by the working group early in the discussion of the public acceptability of criteria development to consider elements in the context of existing wastes.

The panel agreed that there is no known method of assuring public acceptance of the criteria in advance. The degree of acceptability will be enhanced by the amount of openness in the criteria decision process and by the amount of information provided to the public about the risks, benefits, costs, and uncertainties associated with implementing the criteria.

HOW SHOULD THE OPINIONS OF DIFFERENT SECTORS OF THE PUBLIC BE EVALUATED IN DEVELOPING CRITERIA AND STANDARDS?

The present approach to incorporating differing opinions is flawed because of (1) the timing of the opinion-gathering process; (2) the polarization of opinions; (3) the appearance to some of little social, moral, and ethical value consideration by either industry or the Environmental Protection Agency (EPA); and (4) some feeling that there is little technical understanding among the general public.

Improvements on the process of integrating social values of different sectors of the public into the decision-making process is necessary. The most logical and detailed of the alternatives were recommended by one member as a several-step process. The most important steps involve:

1. The communication of public values to engineers during the formulation of the problem and criteria stage.
2. Individual and interest group values need to be identified in a creditable and viable manner.
3. The identification of the consequences of each technical alternative in terms of the values associated with the general public and interest groups as defined above.
4. The identification of the key values of alternatives and the dissemination of this information to the public through the interactive process.

The feeling of the group was that this alternative needed further exploration. A suggested method for defining public values which might be useful in the above alternative was given by a member: a complex judgment methodology.

The idea of a "science court," a process of peer argument and review, and an industry standards approach were also discussed. There was no consensus on these approaches.

Some opinions were expressed (not necessarily consensus) that EPA credibility is questionable, and that its mandate is unclear. Areas in question were: (1) EPA's ability to be both advocate and judge; and (2) EPA's capacity to integrate both social and technical values.

The polarization that surrounds the issue of nuclear energy has affected perception of the risks and the attendant capability of evaluating criteria. The recommendations in this question should not be necessarily applied to this effort (i.e., please do not go back to START).

HOW DO WE DETERMINE PUBLIC ACCEPTABILITY OF RISK?

Public acceptability of risk from radioactive waste disposal is a function of calculated risk and perceived risk. Working Group 3 concluded that there are or might be marked variations in acceptance of risk on a short-term as opposed to a long-term basis. There appeared to be consensus that public acceptance or rejection of risk will be a function of prior information, although the Workshop did not resolve questions of what constitutes adequate or appropriate prior public education on this issue.

Risk-related issues of public acceptance included:

1. The temporal issue. The group suggested but did not clarify a distinction between public willingness to accept risks on a short-term as opposed to a long-term basis. It was suggested that the waste legacy, addressed in the Issues and Objectives Statements, should not be greater than the perceived or calculated risks that we are willing to live with today. Some participants pointed out that protection of minority rights, in this case including those of the future generations, must be considered in addition to majority opinion of the present population on acceptability of risk. A group member stated that part of the legacy required transmission of warning information as well as record-keeping for the benefit of future generations. There was discussion that our disposal methods should not rely on such communication for their success.

2. The spatial issue. There was general but not total agreement that criteria and standards must be accepted at the national level. Some members believed that such acceptability should be determined by a national referendum. Some members believed that local acceptance of risk by those who would be most directly affected by a specific waste site was expected to be less readily obtained. A suggestion was made that criteria and standards stringent enough to satisfy more rigorous local objections would be a better limiting case than criteria and standards acceptable to the national majority, for whom perceived risk would be less immediate in distance or time.

3. The consequence versus probability issue. Some members suggested that low-probability/high-consequence events would be assessed differently from events of less severe consequences, with a heavy

negative weighing on the high-consequence event. It was recommended that consequences analysis should include all detrimental impacts of releases to the environment.

It became clear to the group that perception of risk involves more than use of calculated risk. A list of various factors that enter into risk acceptability and go beyond the consequence-probability estimation was read. Related to this was an observation that technical models of risk do not embody all the factors entering into perceived risk and its acceptability. Risks need to be compared with other risks that are known and accepted.

4. The cost issue. Some members of the working group favored risk analysis in terms of economic cost-effectiveness of consequence mitigation as well as health and environmental costs. Others recommended that health and environmental costs must form the primary basis of risk assessment presentations to the public. In the discussion of risk-benefit analysis it was also suggested that the term "benefit" should not be used in connection with making trade-offs in the cost-benefit analysis for existing wastes.

5. The values issue. It was suggested that consequences must be identified and evaluated in terms of the range of society's value systems. One suggestion was that perception of criteria and risk acceptance by the public would be increased by guaranteeing that only a limited quantity of waste would be committed at any given site.

6. The timeliness issue. Public acceptability of risk will vary with time. In order that the criteria be durable, the need for various mechanisms in the criteria process to reflect this time variability arises. Various mechanisms were suggested: review processes, periodic termination of criteria unless reviewed/reinstated, and criteria for the experimental process of developing disposal methods and sites.

7. The conservatism issue. The role of conservatism in criteria in producing (or not producing) public acceptance of risk was discussed. A wide variety of views was expressed. Some saw conservative criteria as leading to public perception of increased risk rather than greater public acceptance. Others saw conservatism of criteria as increasing acceptability in that they reflect both the changing state of scientific knowledge and also the likelihood of changing circumstances outside the purview of the criteria. It was pointed out by one participant that sufficient

uncertainty exists in our knowledge of low-level and delayed radiation effects to justify extreme conservatism in standards. There was disagreement on the degree of conservatism desired in criteria and standards.

Some participants spoke strongly for zero release and zero dose. Others suggested that waste disposal numerical standards greater than zero would be acceptable to the public.

WHAT INFORMATION, IN WHAT FORM, IS REQUIRED TO ASSURE A HIGH LEVEL OF COMPREHENSION OF THE MAJOR AND MINOR ISSUES RELATED TO RADIOACTIVE WASTE?

Agreement appeared to exist that EPA should make a considerable effort to provide information that is understandable to the layman on impacts of radioactive wastes. The information should, at a minimum, include the following:

1. Fact sheets that address technical issues should be developed as soon as practicable. Areas of technical uncertainty should be clearly indicated. The range of views on issues should be clearly presented and attempts made to identify and fill information gaps.
2. An identification of value judgements that EPA is using to make decisions related to the development of nuclear waste management criteria. The primary focus should be on risk values, legacy values, and public acceptability.
3. The nature of the process and the time schedule being followed by EPA in its program for criteria development (e.g., page 20-26 of EPA's 520/7-76-007 small handout leaflet). The EPA was criticized for not widely publishing this information sooner.

A few participants expressed the view that attempts should be made to identify points of misinformation and to provide the correct information. A desire was expressed to know about EPA's role with respect to other agencies and in particular its ability to assure that criteria and standards would be implemented. It was felt that information on these areas should also be communicated by EPA.

The format in which any information is presented should clearly depend upon the type of information, as indicated above. In general, more than one type of format and mode of communication should be used. These materials should be innovative and be done by professionals with representative input from public interest groups, industry, and government. One type of innovative approach proposed as an appropriate model for eliciting public participation was the U.S. Forest Service's public participation plan for the Manzano Mountain Land Use Plan. Mechanisms could include:

1. Special documentary presentations, both government- and nongovernment-produced.
2. Scientific reports (National Academy of Science studies, government agency reports).
3. Polls and public forums--to ascertain the value judgments.
4. Brochures and leaflets.
5. Annotated bibliographies.
6. Moderated dialogues.

Some of the participants felt that efforts should be made to gain prime time when television is used. Other types of communication modes that were suggested include the following:

1. Automated cards picked up at local community service depots (e.g., post offices, grocery stores).
2. Syndicated news media (press, radio, TV).
3. Utilization of EPA regional offices for dissemination of information.
4. Scientific journals (refereed).

ARE THERE ALTERNATE MODES OF PUBLIC PARTICIPATION FOR DEVELOPING CRITERIA AND STANDARDS FOR RADIOACTIVE DISPOSAL WHICH WOULD BE MORE COMPREHENSIVE AND PRODUCTIVE THAN THOSE CURRENTLY BEING USED BY EPA?

In addition to the forms of information presented in the previous question that directly involve public communication, various other mechanisms were considered that EPA should include for obtaining public participation. A major recommendation on EPA's proposed process was that EPA should definitely hold a public forum for discussion of the draft criteria before they are finalized. This forum should be designed to promote full public discussion of the draft proposed criteria.

It was also recommended that in obtaining public input EPA should make a definite effort to reach the unaffiliated public. A key requirement expressed was that such meetings should be held on nights and weekends.

Mechanisms to encourage greater public involvement were considered. One suggestion made was to use the concept of "distributive justice," i.e., assigning waste for disposal to each county in the nation on the basis of population, to make the entire public aware of the problem and to stimulate their direct involvement in any public decision process.

Polls were suggested as a viable means of obtaining a view of the public's perception of issues, the degree of its concern, and a measure of its knowledge. It was felt that the results of such polls would greatly aid in the development of issues to be addressed and the formulation of criteria and standards to resolve them. Such polls would have to be professionally developed and conducted, however, to be of most value.

At least one member was highly critical of time-bounded public meeting processes such as this Workshop. He labeled the breaking up into groups as "manipulation" and called the Workshop session a "crisis- and panel-dominated situation." Another member said future public meetings should have the format of the present Workshop, since it was conducive to better communication and clarification of points. A third member was concerned about the "speech-making" that the larger working group engendered and felt that "people seem to talk more accurately in small groups."

Several participants felt that the public has to be given a chance to decide acceptability directly through a referendum or similar mechanism.

TOPIC 3 EXECUTIVE COMMITTEE

PUBLIC ACCEPTANCE OF THE RISK ASSOCIATED WITH RADIOACTIVE WASTE

NAME	AFFILIATION
Elaine Baca	Seers Rio Grande Weekly
Robert S. Brandschaim	Citizen
Harriet M. Collins	Concerned Citizen
Richard J. Denney, Jr.*	Office of the General Counsel, EPA
Frederick Forscher	Consultant, Pittsburgh
Marc W. Goldsmith	Energy Research Group
Stephen J. Hammalian	Ecological Analysts, Inc.
Alan S. Hanson	Yankee Atomic Electric Company
Judith H. Johnsrud	Co-Director, Environmental Coalition on Nuclear Power
Lawrence P. Jones	Pacific Legal Foundation
William H. Millerd**	Center for Science in the Public Interest
Terry Mulcahy	Citizens Against Nuclear Threats
Bill Perkins	Atomic Industrial Forum
Robert B. Schainker	Systems Control, Inc.
Robert Spaulding	Southwest Research and Information Center
David C. Williams	Americans for Rational Energy Alternatives
Karla Wright	Native New Mexican - Earth Priestess (Druid)

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* Moderator

** Panelist

RESPONSE OF WORKSHOP PARTICIPANTS TO SUMMARY AND CONCLUSIONS OF WORKING GROUP 3

RICHARD J. DENNEY, JR. (U.S. Environmental Protection Agency, Washington, D.C.): The first question or comment is from Edward McGrath.

EDWARD McGRATH (McGrath & Doyle, Gaithersburg, Maryland): How does EPA relate its contemplation of being overly conservative in setting standards, in the Issues & Objectives Statement, page 3-15, for the purpose of obtaining public acceptance to a statutory purpose of establishing standards to protect the public health?

DENNEY: Jim, this is really an [Environmental Protection Agency] EPA question, so I will let you address that one.

JAMES E. MARTIN (Environmental Protection Agency, Washington, D.C.): I am having a great deal of difficulty understanding it.

EDWARD McGRATH: I am curious about the contemplated stating of overly conservative standards to the statutory purpose that has been laid upon EPA to establish standards to protect the public health. I will state it another way. I am wondering wherein your mandate your power to do that by.

MARTIN: I do not recall it exactly, but I think that was raised as a question for discussion at the Workshop. Everything in the Issues & Objectives Statement was put in that format. I certainly do not know of an assertion that we are going to be overly conservative in setting standards. We are going to set the standards by some mechanism which we do not know yet. After we get the public input, after we get these criteria developed, after we assemble technical information. So, I would say that if there is any misintent it should be construed to mean that it was raised as a question for discussion, not a committment by EPA to be extra conservative in setting standards.

McGRATH: That is my concern. Just so that I have it clearly before you, it occurs on page 3-15 of the Issues & Objectives Statement. The point that is made is number 3 and states, "if technological and regulatory overconservatism is to be incorporated into the criteria and standards development process to ensure its public acceptability...." Then it goes on about costs, but it is the premise that I sense in that first part of the sentence that I am asking the question about.

MARTIN: We had a great deal of difficulty on that particular point in the Workshop. In fact it probably led to one person's complete exasperation with the Workshop about trying to define a question. We finally as I think the report makes clear threw the thing out and came up with another question.

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The question mainly was what we mean by public acceptability. I think that was the ground rule on this. It means nothing really except as a focus for discussion and boy we got a lot of discussion on it.

DENNEY: Judith Johnsrud had a comment. And I might say as soon as that question came up immediately there was concern with that statement. We did perceive it. Judith, would you speak?

JUDITH JOHNSRUD (Environmental Coalition on Nuclear Power, State College, Pennsylvania): The report here on what is termed Question 3, how do we determine public acceptability of risks, is the rephrased question that was addressed by the Workshop. This report initially had the first questions that we initially looked at and then rejected [those] in favor of this statement of the question.

DENNEY: The next comment is from Richard Webb:

RICHARD WEBB (Midwest Environmental Protection Associates, Toledo, Ohio): Why did the group neglect to note the unconstitutionality argument I made in their Workshop? I am sincere about this. The Constitution is the supreme law of the land. Future workshops should address who should decide and do so as soon as possible.

DENNEY: The Workshop addressed the questions that the members of our Workshop felt were important. Mr. Webb did appear and make a statement. He was not a member of our Workshop. We did not believe it was necessary to address that question in our Workshop which...(Somebody in the panel had their hand up).

MARC GOLDSMITH (Energy Research Group, Framingham, Massachusetts): I think that there was consensus within the Workshop that that was not one of the functions that we were looking at as a Workshop topic. There is a dissenting opinion, but I think that there was a feeling that that was not germane to what we were trying to do. We were addressing criteria for the disposal of radioactive waste.

DENNEY: Judith Johnsrud.

JOHNSRUD: One additional comment in this regard. I consider the inclusion of Mr. Webb's statement to us and very frankly my feeling in the way in which it was presented in the Workshop was that it was a conclusion or a discussion from another Workshop that was being presented to our Workshop for its record. But I would have to concur with Marc that we did not then proceed to discuss the issue any further in the limited time we had.

DENNEY: The next question is from Jack Briggs.

JACK BRIGGS (Citizen, Raton, New Mexico). Has EPA really done an in-depth, superimposed study of where radioactive materials will actually be present in the proposed expanded nuclear reactor program?

DENNEY: He wishes to make a comment from the floor. Would you like to do that now?

BRIGGS: I would first like to know the answer to the question.

DENNEY: Jim, do you want to handle the EPA questions?

MARTIN: No.

BRIGGS: The matter of an in-depth study on where this waste will be and not only this waste but all radioactive materials, I think really is a very serious thing which the EPA, if it is going to justify its existence, and I am sure you are trying to do that, I believe you should make a deep study on that. Now may I illustrate very briefly on that. Imagine on any of these walls here a full-size picture of the United States. Put on that picture the location of every mine for uranium, where we get some radioactive release. Put on there every one of the eight processing and so forth plants and what have you that are used in the final production and use of radioactive or nuclear energy. Put those on the map. Put on the map all the hospitals that use radioactive materials. Plot all the military installations. Plot on your map all the laboratories and certainly we need them and must have them, and I am heartily in favor of laboratories and continued research into nuclear energy. Plot on the map the routes along which radioactive materials are going. Plot on the map the proposed areas [where they] will be disposed. This is just touching the surface of the many points, actual points, in the United States, which are going to be subjected to radioactive materials. I think you ought to do something in that very much in depth, and I think it should not be kept in circulation of the staff of EPA and ERDA [Energy and Research Development Administration] but I think it should be widely disseminated in the United States of America for us sometimes scantily informed public. Who was it said we are so scantily informed that I think the time may be short on this planet. It was David Lillianthal, the first chairman of the Atomic Energy Commission. So that is my first question, seriously look at a map on which you have plotted these things and ask yourself, "Are we going in the right direction?"

DENNEY: Your second question, "Is America developing or accepting a kind of Buchenwald death camp morality?" We really do not feel authorized to determine what type of morality America is developing so we did not discuss that question.

BRIGGS: That is a very good answer. The reason I asked that question is this. Such people as Senator Gary Hart of Colorado and of course I know the pronuclear people are going to see red when I mention this name, but [he is] also a very well known and respected nuclear scientist, Dr. John Gofman. These people have told us that even if 99.9 percent --and many other people have agreed with it--that if the greater percent of all radioactivity is contained in a 1000 nuclear reactor economy, or even less, that we can expect between 32,000 [deaths] and I think one figure went up as far as 400,000 or maybe 500,000, which I do not even use, or do not think it should be used. But 32,000, conservatively estimated, of our fellow Americans are going to die from radiation exposure if we go into this large-scale radioactive nuclear reactor program. Now, Hitler put them in Buchenwald. They were his enemies. We are talking about doing something like this to our friends. Granted, we are not talking about millions dying but we really do not know, because millions would die perhaps if we had a nuclear accident. But we will leave the accident out and be conservative.

DENNEY: Mr. Briggs, there are other people here, including other people who also would like to have a crack at it that may not have an opportunity to do so if we do not have some time available.

BRIGGS: Okay, fine, I am aware of that. Now I would like to go ahead with that other question I have. Chem-Nuclear has told us in a folder about what a good neighbor they would make to us up in the Raton area. They have told us in this folder very explicitly that they had no problems with radioactive accidents previously. Thank goodness for what free press we have left. A very sharp reporter here in Albuquerque came up with the finding that Chem-Nuclear had in fact had a nuclear accident at Barnwell. What I would like to leave this group is [a] question. If they have misled us in that way, should not we be exceedingly careful about these glorious statements they give us about their safety in the future? Thank you very much. I deeply appreciate the chance to talk to you.

DENNEY: Thank you, Mr. Briggs. The next comment is from Terry Mulcahy.

TERRY MULCAHY (Don't Mourn, Organize group, Albuquerque, New Mexico): I apologize for being part of the group that produced this and also having a comment on it but I felt I needed to put this before the entire body. There is no mention made anywhere of contacting the average worker involved in the transportation and burial of radioactive waste, including rank-and-file members of the unions involved. I mention this because I previously had some experience with tritium and carbon-14 and had to reconcile my conscience with its being buried and dumped into the Chesapeake Bay in short-lived containers. I also feel that there will be a lot of problems involved if all these people involved in the entire nuclear industry, involved in all these phases of moving the stuff around, in the manufacture, mining, any phase of operation, if these people are not contacted as soon as possible as to how they feel about this and given all the information that we have requested be given to the entire population.

JOHNSRUD: I think that, I do not know whether I can say that an apology is due, but I would like the record to show that indeed this was brought up in our Workshop and was discussed at some length. And I had it among the checks to be included in the discussion of the assessment of risk and in the written discussion, and I must apologize to you Mr. Mulcahy, it was an oversight in the constraints of time we suffered last night.

MULCAHY: I had one more comment. I just want to include it in the record. There are people that are trying to determine what are acceptable levels of radiation. One of these organizations is the Inhalation Toxicology Institute that....has on the airforce base. I applied for a job out there and spent most of the interview trying to field questions concerning nuclear energy which has nothing to do with the installation there. Most of the questions concerned the absolute necessity of nuclear power. I do not feel that such an installation which is trying to determine acceptable levels of radiation should be asking questions like this, should be prejudiced in hiring the kind of people that they are going to have making these tests and should have spent and wasted my time with this incredible discussion of the absolute necessity of nuclear power.

DENNEY: The next question is from Anne Kunze.

ANNE KUNZE (Friends of the Earth, Alpena, South Dakota): There are a variety of ways to provide for public information programs to increase the level and the accuracy of the information and knowledge among the grassroots members of society on the issues so that informed decisions can be made by the voters and citizens on public policy issues. One of the most effective is to identify public interest groups which can sponsor, locally or on a statewide or national basis, public conferences, forums, seminars, workshops, media programs and other events to address various issues and to encourage them to undertake such programs and offer technical assistance, financial assistance and educational resources, including unbiased audio-visuals and printed materials and the services of speakers or resource people to participate in such activities. It is important to require that the information provided be as accurate and balanced as possible and include consideration of values, as well as technical information. With such support and encouragement public interest groups can apply to the National Endowment for the Humanities or their state humanities committees for supplemental funding for planning and conducting balanced discussions of these public policy issues. I would urge that EPA utilize some of their funds and personnel to establish working relationships and assistance to national, state or local public interest groups in order to achieve better grassroots public education and information levels. Thank you.

DENNEY: This is a comment from Robert Spaulding.

ROBERT SPAULDING (Southwest Research & Information Center, Albuquerque, New Mexico): I would like to add my voice to those who feel that this has been an inadequate attempt to get public input. Timing, prior notice, and format of the proceedings have not been good. The large number of 'hired guns' on hand from industry leaves the citizens and citizen groups present at quite a disadvantage. The feedback process has also been wholly inadequate.

I want to pick up on something the last speaker said also. I do not know exactly how that got left out of our review of what went on at the Workshop but that certainly was discussed and was part of it. It really should have been in the body of suggestions made. No, it really was not spelled out in terms, the way she did, as clearly, and also in a way that really comes across. Anyhow, to pick up on the last point of those other ones that I made and that is the feedback question. I really think that that has been a big problem, that there has not been good feedback on the proceedings as they went and also now the final thing, I sort of sense that this is the last time to say anything about what is going on here, what I felt happened here. That bothers me. A small point related to that, there was a statement made, agreed upon wording for the text that in my mind was arbitrarily changed late in the night, and it really upsets me because I see it as a crucial point, or a crucial issue that was discussed in probably every Workshop including ours.

DENNY: To clarify one thing, when you say arbitrarily changed, you mean by the Working Group or by sources unknown.

SPAULDING: No, it was changed by Jim Martin actually. It was not changed by the Working Group at all.

DENNEY: I do not think...Jim, did you make a change?

MARTIN: What change are you referring to?

SPAULDING: The bottom of 3-58, the last paragraph.

MARTIN: We can put it back in. I thought from the discussion that was occurring that there was not the need for the term "crucial link," but if Bob feels it should be "crucial link" put it back in.

DENNEY: Okay, is that what you were concerned with, the word, "crucial?"

SPAULDING: Actually, I was concerned with the process as much as what happened. It just bothered me that it was a crisis situation where that kind of sort of arbitrary thing could happen.

DENNEY: One of the things I am concerned about and I want to sort of clarify it is that no EPA people sat down with this afterwards and went through and edited it out. In fact there are a lot of people up here that would be letting us know if we did. Our work group went to 1:15 at night, either we are very careful or very slow, I am not sure which, but after that the only work that was done, to my knowledge, in fact I do not think anything was done. We agreed at the beginning that there could be some editing that could take place by the contractors that are working with us to smooth it out but in fact I do not think this was done. So I want to make it clear we did not go over these reports and then later go through and jigger them around to come out the way we want to at all. There may have been a word problem there but if so that probably arose out of our problems of 1:15 at night. The next comment if from Bob Shainker.

ROBERT SHAINKER (Systems Control, Inc. Palo Alto, California): I am with Systems Control Incorporated and I am speaking as a citizen. One of the views that did get brought up in our session and is appropriate to the gentleman's comments I want to present. That is that there has been a lot of implication that the engineers, scientists, industry, and such, are a premeditated group of people with a manipulative motivation and it was brought up in our committee, in our Workshop, that people did not feel that this was the case at all, and that the working group recognizes the EPA is doing its best under the situation to allow all viewpoints to be presented and is not submerging things or editing things to say or to imply that we are without somebody getting up and trying to say that, there are people with just the opposite viewpoint. Now, the actual truth will never be known, so I am just standing here presenting the fact that there were people with opposite viewpoints as yourself. I have full respect of your viewpoint, however. I just want to express that.

SPAULDING: I feel that I did not present that first part of that question well at all in the written form. I did not really explain it. What I was talking about there is that when you have a large preponderance of people, industry people, what I have called 'hired gun'. In other words, the odds are just not good for the public here, and the potential for the people representing public groups and so forth to be exploited as sort of a token representation present and to be used, laid down on the record that this public interest group was represented, this one, it lends a certain credibility to what has gone on that I have problems with.

DENNEY: I would really like not to get into a dialogue on this, Bob. We have 15 more minutes. I think both comments have been heard to cover the essential differences. The next comment is from R. F. Williams.

B. F. WILLIAMS (Electric Power Research Institute, Palo Alto, California): The discussion on page 3-58 acknowledges the "acceptability" of nuclear waste may be linked in public perception to the government's role in development of nuclear energy. If this is true, establishing a more complete perception of risks and benefits of nuclear energy in the public mind would be required. One cannot be said to have accepted what one does not know about. This reasoning and the observed linkage of nuclear weapons proliferation to civilian uses of nuclear power appears to argue that the risks and benefits associated with the U.S. nuclear weapons arsenal, both manufacture, transport, and emplacement, should be more candidly described to the public. Fifteen hundred ballistic missiles armed with nuclear warheads on first glance would appear to be a greater hazard to public health and safety than 50 (now) or 500 nuclear plants (in the year 2000). There is apparently a difference in public acceptance of these risks, either because of differences in perceived benefits, or unawareness of perceived risks. The nuclear proliferation linkage may now require the candid description of weapons-related risks, not just the discussion of wastes from nuclear weapons production.

DENNEY: I want to say, by the way, although the panel is up here and may have different views, because of the time and also the format I am only going to ask them to respond to questions about what happened in the work group. I am certain that you would get a difference of opinion on some of these comments, if they were allowed to discuss them. The next comment is from Edith Kirby.

EDITH KIRBY (National Health Federation, Albuquerque, New Mexico). Since Group 3, my group, became tied up on matters not related to the purpose of these Workshops, I should like to present some input of the public, as contrasted to those employed by or having other special interests in the nuclear or related programs, or those brainwashed by the above or by government agencies who are dedicated to the promotion of nuclear power. Public recommendations should require (1) guaranteed geologic stability in the area; (2) guaranteed geologic stability for the length of life of the waste; (3) guaranteed perfection of materials and equipment as well as the waste disposal plant; (4) guarantee that all persons handling the waste at any point will be infallible and will make no mistakes; (5) that NEPA [the National Environmental Policy Act] be applied to all waste disposal and that impact statements cover thoroughly health, social, economic and environmental impact from the active life of the radioactive elements buried.

DENNEY: The next statement is from W. A. Lochstet.

W. A. LOCHSTET (Pennsylvania State University, University Park, Pennsylvania): In the discussion of Question 3, "Issues included...[etc.]," paragraph number 1, "the protection of minority rights including future generations must be considered." I submit that future generations represent a majority, not a minority. They, of course, do not have substantial representation at present.

DENNEY: I will consider that a comment not a question. S. M. Nealey.

S. M. NEALEY (Battelle Human Affairs Research Center, Seattle, Washington): Topic 3, page 3-58, sixth line. I suggest changing the word "unpredictable" to "these." "Any changes in acceptability will have some effect whether 'unpredictable' or not."

DENNEY: I think we can only take your suggestion...we do not have the full panel up here but we can only explain what we were thinking. I think we can only note your suggestion in the record. The next comment is by J. D. Shreve Jr.

J. D. SHREVE JR., (Kerr-McGee Corporation, Oklahoma City, Oklahoma): Has the distress voiced by the so-called public interest groups in failures of public notification and public response ever recognized a freedom of the public sector to trust legally constituted agencies to protect them and their families and property by the regulations these agencies have created or will create?

DENNEY: I do not know that is one that our panel can really answer. I can only say that as a member of a government agency that we do try to do as good a job as we can but even having the responsibilities that we do, once every decade or so we make a mistake, and these should be pointed out to us and we will try to do even better in the future in protecting you and your families.

JOHNSRUD: As a representative of one of those so called public interest organizations I would certainly like to say that, if I did not have a good deal of faith in EPA, I would not have bothered to come all the way from Pennsylvania to Albuquerque to discuss this issue.

DENNEY: There are two questions and two comments. Because of the time and the fact that comments can go more quickly and be read in the record, I am going to take these slightly out of order, read the two comments, then get the two comments from the audience that are requested.

JUDY HURLEY (Rocky Flats Action Group, Boulder, Colorado): I approve the concern indicated by the third working group for paying attention in developing criteria for nuclear waste management to moral as well as economic values. What I would like to advocate in this regard is that we, as one whole society not really divisible into agencies and interest groups, include throughout our public education system, from the earliest grades through all educational levels where it is now lacking, the cultivation of that sort of moral sensitivity and awareness of the consequences of our economic activities.

DENNEY: The next comment is from Dan Schrader.

DAN SCHRADER (Citizens Against Nuclear Threat, National Health Federation, Albuquerque, New Mexico): I am not in any sense of the word a nuclear expert. However, I never cease to be amazed how vested interests of position and money can cause many intellectuals to rationalize their riding roughshod over the well-being of people. History is full of persons who prostituted their knowledge to achieve short-range economic security while doing untold damage to future lives. Compassion is the foundation of civilization. Without a knowledgeable compassion for all, our most advanced technology becomes a sophisticated global cruelty surpassing the deadly lunacy of Hitler himself. I plead for all of us to follow human well-being as our first priority in all our deliberations regardless of the risk to our jobs and positions.

DENNEY: I have two comments, Harry, do I have time for them?

HARRY PETTENGILL (Environmental Protection Agency, Washington, D.C.): Why don't I make a suggestion. I have some additional comments and I would suggest I put these in the record and the proceedings. Everybody will receive a copy of the proceedings, you will be able to read these at your leisure. Also you may have some additional comments and while time permitting here today before people leave if you have these comments please submit them. They will also be put in the proceedings. I think we are up against a time restriction here.

MARTIN: Can I bring up something that happened. I do not know whether it is quite right to or not and the best way to do it is to get a show of hands from the group. Dick Webb apparently failed somehow or other to make a clarification or addition to Working Group Report 1 [Summary and Conclusions], that he felt pretty strongly about. The issue is whether he was given sufficient opportunity to present that information and get it tacked in and argue for it even as a minority opinion. He missed the chance when the group report was presented and he has asked through one of the EPA people whether he could add that point. My inclination is to let him make it, but I am not going to do it because we have restrained the rest of you from doing that sort of thing. Now, if you agree as a group to let him make it we will let him make it. Can I have a show of hands? For agreement--the point is, can he add at this point?

PETTENGILL: He may at least include it in the record of the proceedings. I have no difficulty with that.

WEBB: I would like to make it now because there is so much to read in this world and you are here and I am the only nuclear engineer here outside of the....

MARTIN: Dick, I am sorry. I think we have been quite tolerant of your coming and going and presenting. You missed the chance. Everybody else had chances; they got their material in. I think we just have to say no.

DENNEY: We would like to wrap the proceedings up. I can assure you that if we get into oversights we will be up to 1:15 again tonight on the drafting because I have already heard about some of our oversights from people that were on our group. I would like to make one last comment. This is the first one of these that I have been to. I was not at the Reston group and I will also say that a lot of my activities in EPA do involve areas other than radiation. I only spend a certain proportion of my time in it. I just want to say how impressed I was with the participation of everybody here and particularly the people in the Workshop I was at, and how strongly I was impressed by the attempt of people with very very different views not only to work together, and try to talk the same language and clarify their differences, but also to stay up to 1:15 at night and work together on getting something out. There were thirteen people in our group that managed to stay up that late and I was there but I do not know that I was one of them. Anyhow, I just wanted to end on that note.

PETTENGILL: Thank you, Dick. I have a few brief comments. So there was no misunderstanding, if you have anything additional to add to the proceedings I would like--Jonas Rosenthal please raise your hand there in the back--Jonas will be available. Hand the materials to him at your leisure before you leave here today and I will see personally that they are included in the proceedings. The proceedings will be distributed to everybody who has registered for this Workshop and anybody who desires a copy of those proceedings may write to the Environmental Protection Agency even if they have not attended this Workshop and receive a copy free. I would just like to say, as you have noted here, I have enjoyed the Workshop and, as you noted at the end here as I travelled about the Workshop working sessions, I noted that Working Group 3 was the most volatile, of course, of any of the working groups. We have appreciated your indulgence. I have gained a lot of information and it was indeed an extreme opportunity to be with you here in New Mexico. With that I would like to adjourn the Workshop.

FURTHER RESPONSES OF WORKSHOP PARTICIPANTS TO SUMMARIES AND CONCLUSIONS OF WORKING GROUPS 1, 2, & 3*

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* Because time ran short at the last plenary session, these comments were taken in written form after the session. They are listed here in alphabetical order.

FURTHER RESPONSES OF WORKSHOP PARTICIPANTS TO SUMMARIES AND CONCLUSIONS OF WORKING GROUPS 1, 2, & 3*

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GARY ARMSTRONG (Albuquerque, New Mexico): It is not true that the political dimension of decision making was not a concern of at least one Group [3] member--me. I repeatedly brought up concerns centered around the secret, undemocratic nature of the history of the development of nuclear energy and that I considered this a characteristic of a fascist government. I also tried to get across the feeling that this meeting is not inviting the public to participate in the decision-making process. Rather that questions in [Working] Group 3 dealing with the public boiled down to the [Environmental Protection Agency] EPA asking people for advice on how to set up their public relations program. We have no part yet in the decision-making process and the nuclear industry has already been in existence for around 30 years. Mr. Webb's points on constitutionality fit in well with my line of thinking, the point I was trying to get across. I regret the censorship used by the draft committees, as political issues were stated as a concern of Topic 3 in the program. Public acceptance means accepting something already decided; that is, the existence of nuclear wastes.

MARC W. GOLDSMITH (Energy Research Group, Inc., Framingham, Massachusetts): Mr. Robert Spaulding's comments during the plenary session were a betrayal of all participants who spent till 1:15 A.M. trying to compromise. It appears Mr. Spaulding's comments were an attempt to sabotage the efforts of a lot of hard-working people. Particularly uncalled for was the direct attack on Mr. Martin of EPA who throughout maintained the highest standards of integrity and neutrality.

During the course of this meeting and in some prepared presentations several members of the "public" hurled many accusatory comments aimed at the integrity, sincerity, competence, and morals of engineers. I feel incapable of expressing the destruction to communication and the difficulty of working openly and freely that these inferences cause. I sincerely hope that EPA and most members of the public realize that we too are fathers, grandfathers, humans, environmentalists, and earthlings. I had come in good faith, with sincerity, with a desire to listen and an open mind to compromise; what I found shook my faith in humanity. I do however believe EPA made a good-faith attempt to provide an open honest forum. I feel it was badly misused.

ALAN S. HANSON (Yankee Atomic Electric, Westboro, Massachusetts): In Working Group 3 drafting, the word "heavy" on line 4 of page 3-5 was deleted. Unfortunately, this word is inadvertently included in the final draft. Please have it removed from the proceedings or at least explain the mistake.

This public forum was burdened by two serious communications problems. The first was the unfortunate resort by several individuals representing public interest groups to derogatory name-calling. This was particularly evident in the plenary

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session and was continued in the concluding session. The second problem of the Workshop was the unwillingness of many individuals to remain within the ground rules set by Bill Rowe in the opening address. The discussions repeatedly degenerated into a debate over the future of nuclear power, rather than remaining on the topic of setting criteria and standards for disposal of radioactive waste. I seriously hope that EPA can sift through the derogatory and irrelevant statements in order to find the useful comments.

M. K. HARMON (Atlantic Richfield Hanford Co., Richland, Washington):

1. Praise for EPA in its attempt to do a necessary and very difficult task.
2. I participated in Section (Topic) 1 and 3 workshops. Actually timing much of the discussion in each, I have the following observation for the record: from 65 to 75 percent of microphone time was given to the antinuclear attendees. Thus, the closing comment by one member that there was inadequate feedback and discussion during the meeting does not appear to be valid. Moreover, approximately 50 percent of what such members said was not germane to criteria, but consisted of diatribe and propaganda. I deeply resent the insults hurled and the pejoratives used by these people (e.g., "murderer," "lunatic"), and suggest that the EPA keep this firmly in perspective when assessing the inputs and sources of the recommendations made in this meeting.
3. As a "biased" member of industry, I deliberately restricted by own comments during the working sessions to those things which I thought would help keep the focus of the groups and moderator on substantive and procedural points rather than using the forum for supporting or advancing self-serving points (or emotionally responding to wild, unsupported charges and deliverately provocative, melodramatic pseudo-scientific "data").

WALTON A. RODGER (Nuclear Safety Associates, Bethesda, Maryland): Throughout this meeting members of self-styled "public interest groups," individuals whose obvious bias is so evident as to be beyond question, have had the temerity repeatedly to call those of us who have devoted our lives to the field of nuclear evergy (and thus in contrast to most of them [we] know what we are talking about): "murderers," "incompetents," "lunatics," and "hired guns." They have consistently called us "liars," questioned our integrity, and, most outrageous of all, have had the gall to call us "biased."

I wish to express my personal resentment of these accusations and of EPA's provision of a forum for, and lack of suppression of, these uncalled-for remarks.

I am proud to be a part of the nuclear industry and to have spent my entire working lifetime in managing and controlling its waste. If every industry, individual, and community had done as well as our industry in protecting the environment, EPA would never have been needed and would not now exist.

SALLY RODGERS (Central Clearing House, Santa Fe, New Mexico): It was my understanding that if no objections were raised to a recommendation it would be adopted as a consensus item. It is incorrect that item 5 on page 2-8 is listed as opinions presented rather than as a consensus recommendation. Agree: (signed) Robert L. Craig, Mike Willingham, Chauncey Kepford, Kent Zook, Benny Benally.

ROBERT B. SCHAINKER (Systems Control, Inc., Palo Alto, California): I believe that the technical community (government, industry, and consultants present) should be recognized by the public interest groups as having as much integrity and ethics as they do in trying to solve the problems associated with nuclear waste management criteria. I personally resent the name-calling that has occurred at this conference. It seems to hinder rather than help solve the problems at hand.

KEITH SCHIAGER (University of Pittsburgh, Pittsburgh, Pennsylvania): About 5,000 years ago the human race was given ten criteria for human interactions. They were generally applicable but short and concise enough to be carved on stone tablets. Attached are ten criteria for radioactive waste management--not direct from God.

1. I am Humanity; thou shalt not place expediency before me.
2. Thou shalt not take unto thyself comfort or profit or simplified solutions in the name of Humanity.
3. Ten half-lives shalt thou consider and plan for; beyond that thou shalt let the issue rest.
4. Consider thy progeny, that their days may be long and healthy upon the earth.
5. Thou shalt not kill nor inflict injury upon thy fellow man.
6. Thou shalt not steal from thy fellow man his share of the natural resources of the earth.
7. Thou shalt not commit analytical abominations in assessing risks or costs.
8. Thou shalt not distort the facts nor attempt to deceive thy fellow man.
9. Thou shalt not covet the resources nor the unspoiled environment that is thy neighbor's.
10. Thou shalt not covet thy neighbor's budget, nor his regulatory authority, nor his criteria and standards, nor anything that is in thy neighbor's bureaucracy.

DAVID C. WILLIAMS (Americans for Rational Energy Alternatives, Albuquerque, New Mexico): Many remarks were made that these proceedings were "loaded" against the antinuclear people; actually any reading of these proceedings would show that they were more than adequately represented.

More fundamentally, there are serious limitations to a proceeding such as this as a means of getting "public input."

1. The great majority of people are concerned about many things in addition to nuclear wastes; they cannot participate in all such forums.
2. Many feel inhibited about speaking in front of government agencies about subjects in which they are not experts; such a meeting as this tends to favor individuals who feel no such inhibition.
3. Mr. Roper's paper said that his polls showed a very large majority believe waste repository locations, etc., should be decided by experts, not the public. Almost by definition, this majority will have very little representation in such a meeting.

In short, participants will inevitably be highly nonrepresentative of the general public. They will be heavily polarized between those who possess sufficient technical knowledge to actively defend nuclear energy versus the dedicated opponents of nuclear energy. Both groups represent a very small minority of the general public; no matter how often the antinuclear people call themselves "public interest groups." I hope EPA will remain acutely aware of the fact that such workshops can never provide a good estimate of the true concerns and beliefs of the general public.

PREPARED STATEMENTS FROM THE PUBLIC

STATEMENT BY E. L. AMONETTE*

I am a registered Professional Engineer, a graduate of the University of Colorado.

In the past few months I have made it my business to learn all I can about nuclear hazards. What I have found out astounds and amazes me, then shocks my sensibilities. How can a civilized nation proceed with nuclear reactors and nuclear weapons programs which produce dangerous carcinogens that will be actively dangerous to life, as we know it, for hundreds of thousands of years? How can we treat nuclear programs in ordinary ways when we actually are dealing with extraordinarily dangerous substances? Surely the common citizen deserves at least a vote on whether to lower his standard of living and do without nuclear devices, or to proceed on the present course.

There is approximately a 40 year delay between radiation exposure and terminal cancer. I suggest that, if this delay were of the order of five years, we would have no nuclear programs today. The public would be shocked into realizing what a hazardous demon radioactivity is, if the persons who have suffered lethal exposure were dying now instead of 35 years later. Some conservative figures, based on known and projected plutonium releases into our environment, show that by the year 2016 (when the effects of early exposures will be apparent in large numbers of cancer deaths) there will have been enough exposures to kill off more than 30% of the U.S. population. This "time bomb" effect could destroy us if our leaders don't solve the radioactive waste disposal problem soon! I might note that nuclear development is over 30 years old. Could it be that much of the current cancer death rate is due to plutonium releases from that development? Doesn't this deserve at least as much consideration as, say, saccharin?

I believe that the burying of radioactive wastes in the earth is impractical. We are dealing with half-lives of over 250,000 years. Geologists tell us that the earth is unstable over a period of one million years, and that stability is uncertain between 1,000 and a million years. In other words, mountain ranges could uplift or subside and earthquakes could create fault lines or fissures in a storage area within the period of time that the buried nuclear wastes are still dangerous. Can we ethically pass this hazard on to our later generations? I think not.

I believe that much more time and funds must be spent investigating the possibility of removing the long-lived actinide elements from nuclear wastes and re-using them in existing

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nuclear reactors. This should reduce the dangerous lifetimes of the remaining wastes from over 250,000 years to around 700 years, greatly simplifying the storage problem.

The most agreeable solution, at least to me, is deep space disposal or terrestrial disposal. I am surprised to learn that very little study has been devoted to sending the wastes out into space on a rocket. Surely computers could analyze the comparative odds of contamination from a launch accident versus a "geological accident" due to predicted earth instability. Strong, hopefully leak-proof, containers will have to be designed in any disposal plan, and it does not seem to me out of the question to design one that would survive a rocket launch accident without leaking. Sending the wastes out into space is the only way I can see to guarantee sparing our descendents the horrors of radiation exposure.

I understand that this Workshop is part of a project to develop radiation standards for radioactive wastes. So far as I can find out, no one knows what constitutes a lethal dose of radiation, so until that is determined how can anyone set other than arbitrary standards for radiation? Arbitrary isn't good enough for me. Complete avoidance is what I will try to practice.

STATEMENT OF A. B. CARSON*

Radioactive waste management generally is recognized as one of the key areas in which national policies and implementing regulations must be clearly and comprehensively defined before the commercial nuclear fuel cycle can be closed, whether nuclear sources supply an increasing or a decreasing share of future electric power and whether or not the method of closing involves fuel reprocessing and recovered product recycle. It is particularly important to prospective source facility owner/operators that rational and consistent criteria be established for protecting the environment against loss of radioactive waste material control in the course of segregation, treatment, packaging, interim storage and transport operations because of the potential impact of such criteria on licensable plant designs and on project costs and schedules. Criteria to be applied to final waste repository facilities are of concern as well because related waste form and packaging requirements also may affect source facility designs and operations significantly.

It has been the general position of industry that the environmental impact potential of radioactive waste management operations can be controlled effectively by methods which have been identified and are capable of application in plant systems. Attainable performance of production-type equipment under the full range of potential operating conditions still would have to be demonstrated more fully in some cases. However, no technical breakthroughs are required for such demonstration effort to proceed on an orderly basis if related policies, criteria and regulations are rationally defined. For nuclear power to make a constructive contribution to national energy supply objectives, it is essential that such definition be made with as little further delay as possible and with more direct consideration of underlying issues than has been accorded to date.

One of the issues that must be more directly addressed before present uncertainties can be resolved in a consistent and lasting manner is whether "acceptable" levels of risk exposure or environmental impact from waste management activities can be clearly defined and, if so, on what basis. Potential risk or impact acceptability must be considered in deciding on waste collection and in-process confinement integrity requirements, form and packaging criteria for each category of waste, repository types and locations for wastes from various sources, etc. This issue therefore must be addressed by all the agencies involved in nuclear waste management, (NRC and ERDA as well as EPA) and their considerations must be on consistent and relatable bases to avoid confusion and contention in later interactions. To date, there appears to be no integration and little communication among the parallel agency programs in this general area. There is no evidence of disagreement that zero risk or impact is not practically attainable and is not necessary as a regulatory requirement. However, there is not general agreement in current discussions and publications on how levels of acceptability can be set, let alone what they should be for fuel cycle back-end facilities where the most radioactive wastes must be handled. Past regulations and licensing procedures which related impact acceptability to rather specific numerical release limits have been challenged as to the validity of their bases (e.g., measurable health effects) and the adequacy of the methods used for their derivation (e.g., allowances for abnormal conditions). Relationships to background conditions or to natural variations in background with time and location also have been cited as bases for judging impact acceptability but differing opinions regarding validity of limits so derived have been expressed here too. The "As Low As Practicable" or "As Low As Reasonably Achievable" approach to regulation that is now being applied tends to avoid the question of whether there is a level of impact that can be considered acceptable, once and for all, but it is most readily applied to an ongoing activity where extensive operating data with existing systems is being obtained and new facilities are being designed and installed at such a rate that evolutionary improvements are possible and, in fact, are almost assured. These conditions do not obtain for fuel cycle back-end facilities where few if any commercial facilities are in operation and not many ever will be required. There are good enough data on source terms, effectiveness of treatment processes and systems, integrity of confinement and isolation provisions, etc., to provide assurance that there need be no measurable effect on the environment and that calculated effects will be a small fraction of background conditions and well within natural variations in background. The general view of industry is that such levels of impact can be considered acceptable, at least for the period required to accumulate the extensive data and experience required for a clear determination of what is ALARA.

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* Member, AIF Subcommittee on Radioactive Waste Management.

A related issue which should be more directly addressed is that of what constitutes an adequate level of process or system demonstration to justify consideration of their availability and functional performance in decisions related to waste management or environmental protection. A policy requiring full scale demonstration over the full range of potential conditions for all such items before source facility operations would be allowed to proceed is not practical and is not really necessary. In some cases, large scale operation of production-type source facilities is the only way to obtain the quantities of particular wastes required for final demonstration of plant-rated systems or provisions. As noted previously, however, there are methods and concepts for accomplishing essential waste management and environmental protection functions which are based on well demonstrated technical and engineering principles, even where specific system demonstration prior to source facility operation is not practical. Thus, assurance of ultimate availability and performance capability sufficient to support broad policy or program decisions can be provided even though determination of ALARA impact or risk, establishment of final regulatory requirements for environmental protection, etc., may have to wait until actual plant systems are developed and their performance and cost characterized in detail. In summary, the levels of demonstration required to support particular decisions or actions must be defined on consistent, quantitative bases.

STATEMENT OF CONSUMERS POWER COMPANY*

Consumers Power Company is pleased to take the opportunity to respond to your request for a formal statement on Policy and Technical Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes.

The safety, adequacy and availability of nuclear waste storage facilities are of vital concern to Consumers Power Company. Our obligation to serve the public with safe, economical and dependable electric power has led us to construct nuclear generating facilities such that approximately 20% of our electrical generating capacity, both now and through at least the mid-1980's, is nuclear. Environmental protection criteria constitute an important step toward a national plan for waste disposal and/or storage, as the case may be. It is a particularly important step in the field of high-level waste where lack of such a plan leads to concern over mounting inventories of spent fuel at individual plant sites across the nation.

Consumers Power Company believes that environmental protection criteria for high-level radioactive wastes should receive a high priority such that their development is rapid, but that this development be undertaken with due consideration of not only the public health and safety, but also of practicability. To whatever extent possible, we will assist your efforts. We are grateful for the opportunity to participate in this Albuquerque criteria Workshop.

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STATEMENT OF MARGARET FARRELL*

Policy statement: From its past record the nuclear industry has shown that it is irresponsible in matters that concern public safety and environmental cleanliness. Because of this, the nuclear industry should have no part in setting standards for the disposal of the nuclear wastes. The public has the right to know what percent of the nuclear industries' profits are being put back into research for determining what to do with the radioactive wastes. No persons or corporations that have any vested capital interests in the nuclear industry should be involved in determining the means by which nuclear wastes will be isolated from the environment so that the citizens of this generation and of future generations will be unharmed. The nuclear industry will be held responsible for providing full-funding to carry out the waste disposal plan.

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STATEMENT OF ERIC GEIGER*

SHALLOW LAND BURIAL

Shallow land burial in a geologically and hydrologically acceptable "container" should be used for high volume waste from nuclear power plants, hospitals and other nuclear facilities. The concentrations and total curies permitted to be buried should be a function of the half-life and radiotoxicity so that the site can revert to "unrestricted use" 100 years after the last waste is buried there. This approach would preclude shallow land burial of radium needles or other concentrated ^{226}Ra sources from hospitals. ^{226}Ra in a concentrated form should be handled the same as transuranic waste, since its control will require the spanning of many generations.

Perpetual care funds for shallow land burial sites that do not accept long half-life radionuclides (like ^{226}Ra) should be designed to last 100 years after the useful life of the disposal site. Environmental monitoring of key pathways (e.g., air and water) will need to be continued after the site is shut down but the program should phase down as the age of the site increases.

HIGH LEVEL WASTE

The volume of high level waste should be kept small, consistent with whatever solidification process is used to render the material inaccessible to normal solubilizing influences. Disposal should be such that perpetual maintenance or surveillance is not required.

URANIUM MILL TAILINGS

Ultimate disposal of mill tailings must take into account long-term control of radon gas emissions. If this is done, re-suspension of ^{230}Th and the other decay products of uranium also will be adequately controlled.

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* Certified health physicist, Nuclear Services Division, Eberline Instrument Corporation, P.O. Box 2108, Santa Fe, New Mexico.

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STATEMENT OF CHARLES HYDER*

SUMMARY

Since this paper is responsive to the proposed nuclear waste disposal program by ERDA (environmental impact statement due Oct. 77), there is not enough time or opportunity to present a completed research work. I present herein the basic buoyancy process by which previously stable geological formations would become destabilized by the introduction of one ton of nuclear wastes. To my knowledge those charged with studying these phenomena are not addressing this buoyant rise process in their studies.

I derive an equation that relates the total energy deposited via radioactivity to the upward lift of the heated environment of nuclear wastes deposited in the earth.

This upward lift results from the thermal expansion of the radioactively heated formations around the disposed nuclear wastes. The thermal expansion results in a decrease in density of the heated region (it becomes buoyant). This lower density region tends to float upward like a bubble of heated air in atmospheric convection. The speed of rise is determined by the amount of buoyant lift (3,000,000 tons or more), the size of the heated region (usually a sphere) and the effective coefficient of viscosity. All of these parameters are related via Stokes' equation for dragging a sphere through a viscous medium.

Thus, the disposal of nuclear wastes in the earth introduced geological instability. That condition is in violation of the first law of geological disposal: the nuclear waste disposal site must be geologically stable.

Not only is the geological disposal site always unstable, it is dynamic. The formations around the wastes will be moving upward tending to drag the wastes along with them. The motions of the waste nodules will depend on their densities. Nodules with a density of 3 or more will sink, those with a density of 1.5 or less will float upward faster than the surrounding hot bubble, and those with density of 2 or so will float upward along with the rest of the hot bubble.

The heating also reduces the coefficient of viscosity just as it does for honey or molasses.

I find that one ton of nuclear wastes will travel upward 100 ft to 500 ft during the first half-life after disposal.

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These dynamic geo-instabilities obviate the stability required for the safe disposal of nuclear wastes in bedded salt, etc. We must look to safe retrievable storage facilities on the surface while we search for a technology that is demonstrably adequate to insure human health and survival throughout the toxic lifetimes of the nuclear wastes.

At present it appears that no technology is adequate for that task. One hundred percent Retrievable Surface Storage Facilities appear to be our only viable alternative at this time.

Details and refinements will follow to define the definitive experiments required to demonstrate the adequacy of any proposed geological disposal of nuclear wastes.

Given the instabilities produced by tons of radioactive wastes via thermal buoyancy, the problem of dynamic manifestation arises.

If one assumes homogeneity, isotropy, and flawlessness, perhaps the radioactively-heated salt would not rise. Perhaps the dense radioactive wastes would not sink. Perhaps all would go perfectly, and nobody would ever get exposed to the carcinogenic nuclear wastes.

But nature doesn't work that way, only the nuclear industry's theoretical models for "normal" operation involve the idealistic perfections described above. What we usually find is that "If something can bleep up, it will." (Murphy III). We usually find that geological formations are characterized by inhomogeneity, anisotropy, incipient instability, extensive faulting, occasional seismicity and other geological activities.

The precise impacts that a large-scale buoyant mass would have on these geo-circumstances are not being addressed by the Sandia geophysicists or by EPA, ERDA, or anyone else we know of. We would like to know how careless ERDA is willing to be with the lives of N.M., Texas and Mexican citizens?

What experiments have been conducted to determine how much buoyant lift can be measured after one half-life? How much upward motion of nuclear wastes would result directly or indirectly from buoyant instabilities in bedded salt? How much would plutonium migration occur in the damp bedded salt? Would the heating and buoyancy effects stimulate water migration to reach human aquifers? And on-and-on.

But say that ERDA's idealistic models are appropriate, and there is no movement anywhere near the heated region. As the heated sphere grows and cuts the surface what happens to the salt/anhydrite made plastic by the rising temperatures? Bubbles and jets of super hot salt/anhydrite laden with radioactive wastes would move easily toward the surface of the earth thru the heated region. A ton of nuclear wastes could produce a few hundred feet of upward motion; would 1,000 tons produce 100,000 feet of upward motion? Some fun! We should be in a position to offer some reasonable theoretical expectations by Jan. '78.

Then we'll be able to provide detailed descriptions of definitive experiments that would establish the validity or non-validity of the buoyancy and dynamics of the hot bubble created by buried nuclear wastes.

STATEMENT OF BROTHER STEPHEN KOSMICKI*

My name is Stephen Kosmicki. I am a member of the Dominican Fathers and Brothers (St. Albert the Great Province), a religious order within the Roman Catholic Church. I am presently a student intern with the American Friends Service Committee in Denver, Colo. My testimony, however, does not necessarily represent the views of my community or the American Friends Service Committee.

I wish to voice my strong opposition to the proposed "disposal" of radioactive nuclear waste materials in underground salt caverns as not only unrealistic but as potentially dangerous to present and future generations. Furthermore, I wish to voice my strong opposition to the further development of nuclear fission powerplants. I wholeheartedly endorse HR882. HR882, a bill currently under Congressional consideration, would "...terminate the granting of construction licenses of nuclear fission powerplants in the United States pending action by the Congress following a comprehensive five-year study of the nuclear fuel cycle, with particular reference to its safety and environmental hazards, to be conducted by the Office of Technology Assessment, and for other purposes."

What is at issue in this series of public Workshops is not simply what to do with already accumulated radioactive waste materials. What is essentially at issue is the continuation and expansion of nuclear fission powerplants. Space does not permit a full exposition of my arguments; nevertheless, I find myself in rather complete and fundamental agreement with the anti-nuclear position on this matter. Harvey Wasserman in a recent editorial (Seven Days, March 14, 1977, p. 36) aptly summarizes this position:

> All nuclear plants give off a certain amount of radiation, and this radiation is a known cause of cancer, leukemia, and birth defects. All nuclear plants are potential bombs. Should the core of even a medium-sized reactor get out of control (either by accident or sabotage), it could release thousands of times more radiation than was spewed out at Hiroshima and Nagasaki. By the industry's own admission, such a catastrophe could kill thousands and cost billions.
>
> All nuclear plants produce radioactive wastes which cannot be handled, which can be turned into bombs, and which ultimately pose an almost incomprehensible threat to the health and safety of this and all generations to come. There is no solution now or on the horizon for the waste problem, and any future remedy will cost billions.

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The Friends Committee on National Legislation (FCNL), which includes Friends appointed by 22 Yearly Meetings of the Religious Society of Friends and by 10 other Friends organizations in the United States, in its policy statement of January 25, 1977, stated, "The world's energy problem is a crucial aspect of the struggle for human survival and welfare on a planet of limited resources. Energy policy formation should be global, not determined primarily by nationalistic, military, or corporate interests. The choices are basically moral: what long-term risks are justified--risks of damage to the environment, or radiation damage to health, and of limitation of the life-chances of future generations?" FCNL also supports a moratorium on all new construction licenses for new nuclear powerplants.

Jacques-Yves Cousteau has eloquently addressed himself to the specific issue of nuclear waste. He writes,

> The basic nuclear issues are at least as much social and ethical as they are technical and economic, because they involve an unusual amount of risk in an unusual form--genetic risk. Even if we suppose--which has hardly been demonstrated--that mechanical and technical and even human failure have practically been eliminated, the problem of radioactive by-products remains. By an enormous factor, products of fission are more intensely radioactive, more plentiful, and more concentrated than are the naturally occurring radioactive materials that evolution has reluctantly accommodated (although life did not evolve at all until most of those materials had been safely locked away).
>
> Both during operation and for periods as long as tens of millions of years--for far longer than human cultures have lasted--the toxic and explosive materials produced in enormous quantities in nuclear plants will have to be meticulously contained. This containment demands that extremely high levels of dedication, vigilance, and quality control be maintained without any interruption, indefinitely--a situation totally alien to the human condition. In other words, safe containment for future generations means that if we go nuclear, from now on all nations of the world participating in the atomic venture will have to be ruled by stable governments and maintain reliable police forces for millions of years! This is simply unthinkable.

Furthermore, we find it necessary to warn that one cannot separate the nuclear waste issue from the nuclear power issue without at the same time running the risk of simply capitulating to the interests of nuclear technologists and bureaucrats. The important decision on these important issues cannot rest exclusively with the aforementioned elite.

The nuclear technologist's perspective is dictated in large measure by an overriding concern with technique. He (or she) does not ask whether or not the technology behind nuclear energy is something that is moral or immoral, ethical or unethical. As a technologist he is indifferent to these questions. Generally, what is considered to be possible for technology will be accomplished by technology. This is the ruling principle that motivates the nuclear technician. In this regard Russell E. Train, former head of the Environmental Protection Agency, notes, "What I have come to see more and more is a technology increasingly out of control in terms of the ability of human society to manage it." (Rocky Mountain News, February 20, 1977, p. 47).

Likewise, the bureaucrat--be he a representative of big government or big corporations--does not bother himself with the ultimate questions. He is concerned primarily with the smooth and efficient running of the particular organizational machinery of which he is a part.

To repeat, the important decision about nuclear energy and its consequences (e.g., nuclear waste) must be informed by values which are different--even hostile toward--the values already mentioned. Without taking this fact into account the ultimate questions are never asked let alone answered. These ultimate questions include, "Is it just to leave future generations a legacy of radioactive waste with a lifetime of two hundred and fifty thousand years? Is it just to risk the further proliferation of nuclear weapons, and therefore nuclear war, via the proliferation of nuclear power? Is it just for us Americans to maintain our present level of energy consumption whatever the terrible toll that is exacted as a result on the rest of the human community and the earth's environment?"

We trust the answer to these questions will be a resounding "NO!" and that we will move beyond the passing foolishness of nuclear power to other more reliable sources of energy (solar, wind, geothermal, etc.) that do not threaten to destroy the health and genetic well-being of the human family and the earthly environment.

STATEMENT OF MORATORIUM, INC.*

I am writing this letter on behalf of the Board of Directors of Moratorium, Inc., a recently formed non-profit New Mexico corporation which has been created for the purpose of developing information and insuring public input with respect to the proposal of Chem-Nuclear New Mexico, Inc., to locate a low level nuclear waste disposal site in Colfax County, New Mexico. We are a membership organization and represent a large number of interested Colfax County citizens.

We are unable to have a representative attend the hearing which you are conducting in Albuquerque during the week of April 11, but wish to make our feelings known with respect to the issue of Federal Regulation of low level nuclear waste disposal.

It is the position of our organization that new low level waste disposal sites should not be licensed until adequate Federal and state regulations imposing adequate safeguards have been developed. We feel that those regulations should include the following criteria for licensing of new low level waste disposal sites:

1. No new low level waste disposal site should be licensed except upon application to the New Mexico Environmental Improvement Agency and prior to a mandatory three year period for consideration of the license application. The purpose of the three year period is to insure an opportunity for input from citizens representing the private sector affected by a proposal to license a low level nuclear waste disposal site. The nature of citizen input is such that it cannot practically be accomplished at an effective level without an opportunity for the private sector to hire independent experts to evaluate information presented by the applicant to a licensing agency, and the private sector cannot obtain or insure the availability of such expert input without substantial time for organization and fund raising. We regard a three year consideration period as a minimum necessity.
2. That an independent application or a license to dispose of low level waste be filed with the NRC, and that a similar three year mandatory consideration period be imposed for the reasons stated above.
3. That no application for a license to dispose of low level waste be approved without the prior approval of the County Commission in which county a disposal site is proposed to be located, so that any location of a nuclear waste disposal site will be consistent with long range local land use planning.

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4. That the approval of any license to locate a low level nuclear waste disposal site be subject to review at the next regular or special session of the state legislature, and that the state legislature have the power to withdraw the approval and licensure.
5. That the citizens of all counties affected by the application for licensure or by the licensure be permitted upon the initiative and petition of not less than 1,000 persons to put the issue of licensure to a referendum of the citizens of those affected counties, and that the majority of votes cast at any special or regular election held with respect to the issue of licensure be controlling with respect to the location of a nuclear waste disposal site.
6. That no license be issued unless it is determined that there is a national and local necessity for the location of the nuclear waste disposal site at the place proposed in the application and during the period proposed in the application.

STATEMENT OF PACIFIC LEGAL FOUNDATION*

Pacific Legal Foundation (PLF) submits the following statement concerning the Environmental Protection Agency's (EPA) proposal to develop environmental radiation criteria and standards for radioactive wastes. 42 Fed. Reg. 15433 (March 22, 1977). PLF's interest in this matter is set forth in its comments submitted January 26, 1977. Being fully cognizant of the need for care in isolating certain by-products of the uranium fuel cycle for a significant period of time, PLF nevertheless, urges a balanced approach to the setting of standards and criteria governing this matter. Further, in light of the fact that we are now faced with the problem of isolating significant amounts of radioactive by-products already in existence, it would be inappropriate and counter-productive to adopt unrealistic or unachievable standards.

If nuclear energy is to be employed to alleviate this nation's present dependence on dwindling fossil fuel supplies and unreliable petroleum imports to meet its energy needs, it is imperative that decisions affecting the disposal of radioactive by-products be made with dispatch. Accordingly, "...mere argument alone must not be permitted against the principled judgment of agencies charged with the protection of the public interest to bring essential economic development to a standstill by magnification of slight possibilities into the horror of impending doom" (Ref. 1). While public input is desirable and often beneficial, in making decisions such as EPA contemplates, PLF urges EPA to weigh this input against the findings of responsible agencies such as the Nuclear Regulatory Commission and the Energy Research and Development Agency. In addition, the findings of independent researchers in the field should be accorded great weight.

More importantly, uninformed or imposturous persons clothing themselves as representatives of the commonweal should not, on that basis, be allowed to influence EPA's decision as to what criteria and standards should be adopted.

Mere recitation of substantially large organizational membership or affiliation with several similar "public interest" groups should not suffice to support such representations as "the public expects zero emission from waste repositories." Such unrealistic approaches to the problem at hand are nothing more than irresponsible attempts to prevent the use of nuclear energy by the private sector. This is not only contrary to the express intent of Congress (Ref. 2), it overlooks the resounding defeat of several statewide referenda intended to achieve the same goal during the 1976 election (Ref. 3).

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EPA must also bear in mind that overregulation injects crippling and costly economic burdens and uncertainties into the private sector's attempts to utilize nuclear energy (Ref. 4). Thus duplicative regulatory efforts should be avoided (Ref. 5). Clearly when the costs of regulatory compliance become unbearable or the accomplishment of applicable standards and criteria become unachievable the use of nuclear energy by the private sector will be abandoned. Hence the adoption of non-cost beneficial standards would disserve the public interest by depriving the public of the benefits to be derived from its safest and most abundant near-term alternative to the present energy shortage.

Finally, EPA must consider the effects of its decisions on the international posture of the nation. No standards or criteria should be adopted which would detract from the ability of the United States to compete effectively in the present struggle for leadership in the use of nuclear energy for peaceful purposes.

REFERENCES

1. Citizens for Safe Power v. NRC, 524 F.2d 1291, 1301 n.15 (D.C. Cir. 1975).

2. See, e.g., 42 U.S.C. §§ 5801 *et seq*.

3. See, e.g., "Fallout from the California Nuclear Initiative" 6 ELR 10174

4. See, e.g. Nucleonics Week, March 24, 1977, at 6 ("...FP&L has just canceled two 1,160-Mw nuclear units after a $20 million investment 'out of frustration with the licensing process and escalating costs'"). *Cf*. also, Washington Post, March 17, 1977, at E-1 ("Customers of the Virginia Electric and Power Co. may lose as much as $146 million if the company cancels construction of two reactor units at its Surry nuclear power plant....").

5. See, specifically 42 U.S.C. § 5820.

STATEMENT OF ALEXIS PARKS*

I have been carrying around an interesting statistic for several months that reads, "1/2 of 1% of the public has ever attended a public meeting and of this number, only 0.2% has felt that their participation has had any influence in the decision making process."

This statement is also endorsed by the Woman's Strike for Peace, of Southern California.

In 1946, the opening paragraph of the Atomic Energy Act cautioned: "The effect of the use of atomic energy for civilian purposes upon the social, economic and political structures of today cannot now be determined."

Thirty-one years later, that effect still remains undetermined. Thus the EPA has asked the public--those people who have indirectly (through taxes) financed the basic technology of nuclear power and thereby involuntarily assumed its risks--to identify those social, moral, political and technical impacts that have some bearing upon the EPA's (as yet undeveloped) environmental protection criteria for radioactive wastes.

The Rocky Flats Action Group (.....) is pleased to lend its expertise, borne [sic] of experience and research, and among some members--scientific backgrounds--to this conference, but we must qualify our participation by stating that it is impossible to refer to the ethical, moral, political and technical issues surrounding radioactive wastes from atomic energy without recognizing that these wastes are generated at every stage of the nuclear fuel cycle: beginning with their accumulation at the uranium mines and milling sites, the conversion processing plants within the nuclear reactors, and with their stockpiling in trenches and in (in some cases leaking) storage tanks. If we have omitted final deposition sites from this list, it is because none at present has been demonstrated and licensed as safe for the "forseeable future."

Further, to ignore the building pressure of a continuously expanding radioactive inventory while technological solutions are not yet in hand, is to encourage a greater risk of error or accident, or to encourage the hasty, less than acceptable disposal of those accumulating wastes.

Therefore, while we agree that it is our ethical responsibility to develop acceptable, permanant [sic] disposal methods as soon as possible, we would suggest that it would be difficult to discuss those issues pertinant [sic] to developing EPA protection criteria without first recommending that any further

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* Rocky Flats Action Group, Denver, Colorado 80206

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generation of radioactive wastes cease (under some reasonable reduction procedure) until such time as permanent storage technology can be demonstrated and licensed as safe.

The following statement is from U.S. (Colorado) Representative Pat Schroeder, taken, with permission, from personal correspondence:

> Until nuclear technology is developed to the point where we don't have to worry about health and environmental dangers, the Clinch River Breeder Reactor Program as well as all other such programs should be brought to a halt.

It will be a great day when our daycare centers have all the money they need and Rockwell International has to hold a bake sale to buy plutonium for nuclear bombs.

STATEMENT OF KEN SCHULTZ*

Good afternoon. I'm Ken Schultz and I work for the Southwest Research and Information Center, a technical and legal support center for community groups and citizen organizations concerned with environmental and social problems. On behalf of the Albuquerque Chapter of New Mexicans for Clean Air and Water we have been looking at the problems of radioactive waste disposal since ERDA first announced its interest in disposing of high-level waste in the Carlsbad area. Now we are interested in commercial low-level disposal as well. Quite aside from radiation hazards, we have identified several areas of concern which affect our confidence in the nation's radioactive waste disposal program. My comments today, with one exception, deal with low-level waste disposal.

Let me start with the exception. We are concerned with a loophole in Federal regulation that will permit the Energy Research and Development Administration to establish a high-level waste site near Carlsbad, or anywhere else, without first getting a license from the Nuclear Regulatory Commission. This may occur, we understand, through the coupling of two provisions of Federal law. One provision prohibits the NRC from regulating the disposal of radioactive wastes of military origin. The other exempts ERDA research and development projects from NRC licensing.

Thus, if ERDA chooses to describe the Carlsbad operation as a "research and development" project, and if it chooses to dispose of military rad-waste there, it can evade any NRC control over the whole operation. After a short while, ERDA may proclaim the site to be safely demonstrated and proceed to full scale operation with commercial wastes. Thus, the NRC--the Federal agency most responsible for protecting us against radiation hazards--would have had no input into the decisions on site selection or plant design. Is this the way to deal with such hazardous products as high-level radioactive wastes?

To proceed with my comments regarding commercial low-level radwaste disposal:

1. The Nuclear Regulatory Commission's Agreement State Program permits subversion of the environmental impact assessment process mandated by the National Environment Policy Act in the following way: The Atomic Energy Act allows a state to accept the responsibility for regulating certain uses of radioactive materials _if_ the state's regulatory program is "compatible" with the NRC's program. It is frequently noted that NRC-licensed low-level disposal sites must be located on

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Federal or state owned land, and that therefore, a state-licensed site must also be on Federal or state owned land. New Mexico officials recognize this requirement. Such a requirement is indeed "compatible."

We are puzzled and disturbed, then, when we are told that, although NRC regulations clearly require a full NEPA-type environmental impact statement prior to the licensing of a commercial low-level radwaste dump, such a full NEPA statement will not be required for a site licensed by the State of New Mexico. We are told that this is because there is no New Mexico state law requiring environmental impact statements. This curious elevation of the absence of state law to a higher regard than clearly stated Federal regulations offers a unique logical inconsistency that will, no doubt, sooner or later find judicial resolution. In the meantime, such flagrant and officially approved "incompatibility" with the Federal radiation control program undermines public confidence in government at all levels.

2. It is widely recognized that the low-level radwaste disposal program of the past provides an inadequate basis for decision making today. Fifteen years after the first low-level dump received its license, authorities still do not have adequate standards or criteria for the operation of such a site, for monitoring conditions there, or for determining when radioactivity migration has reached unacceptable levels. Authorities say we don't even know how to select a suitable site in the first place. Neither have they ever adequately investigated alternatives to shallow land burial. The logic by which the whole nuclear enterprise proceeds is peculiar at best.

3. We are also worried about the liabilities to the state's economy presented by a low-level radwaste dump within our borders. As the NRC staff recently noted: "No national standards are available by which States can evaluate the adequacy of existing perpetual-care funds or collection rates, evaluate proposed changes to perpetual-care charges, or evaluate amounts that might be needed for corrective actions if major problems develop in site operation. These standards should be developed." Indeed they should. Before any additional sites are licensed.

   When the numbers and mechanisms are finally known, it is the waste-makers and the dump-site operator, not state citizens who should bear the costs of licensing, inspection, monitoring, and long-term care. Radioactive waste disposal is a national problem and should not be subsidized by the citizens of a few selected states. Indeed, our legal staff has advised that it may violate the state's constitution for New Mexico to assume long-term care responsibility for a commercial radwaste dump. The written opinion is available from our office.

STATEMENT OF RICHARD E. WEBB*

This is a summary of my treatise on "An Inquiry of the Safety of Nuclear Waste Disposal and the Accident Hazards of Spent Fuel Storage Pools in Nuclear Power Plants."

The potential for contamination of the biosphere by seepage and dispersal of highly radioactive nuclear waste is staggering. Assuming 1,000 reactors operated for 100 years, the accumulated waste could potentially contaminate 50,000 large rivers--each of the size of the Ohio River--for 100 years above the maximum permissible level for drinking, due to seepage of buried strontium-90 radioactivity alone; or contaminate a large geographic area of the size of Illinois, Indiana, Ohio, and half of Pennsylvania combined (150,000 sq. miles) so as to require agricultural restrictions if just two millionths of the amount of strontium-90 that may be stored in surface storage facilities were released into the atmosphere in an accident. Similar magnitudes of disaster potentials can be shown for cesium-137 and plutonium waste.

After terminating a waste disposal project in underground salt formations in Kansas, the U.S. Atomic Energy Commission in 1974 chose to dispose of waste by storing it for 100 years in water-cooled surface storage basins. Fifty thousand such basins would eventually be needed in such a plan, to store the waste generated in consuming the high-grade uranium ores, assuming the breeder reactor is used to extract the full energy potential in the uranium. Each basin could suffer a meltdown accident, explosion, and vaporous release of radioactivity. Each basin would have 150 million curies of Sr-90; so if just 2% of the Sr-90 were released from one basin, one-half of the land east of the Mississippi River could be restricted agriculturally if most of the radioactivity fell out on the land due to rain. The government has never analyzed the basin meltdown accident.

The U.S. Energy Research and Development Administration (ERDA) has now re-chosen deep underground burial of waste as the preferred disposal method, and is moving rapidly to select the first six sites. Forty five states are considered to have suitable geologic formations for placing waste. ERDA is planning to have ready by 1985 a pilot facility in a rock salt formation for receiving waste. Ultimately, 18,000 such facilities would be needed, each of which would have the potential

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* Nuclear Engineer and author of The Accident Hazards of Nuclear Power Plants (University of Massachusetts Press, 1976). Attendence sponsored by the Midwest Environmental Protection Associates, Mapleton Intervenors, and S. Gadler, member of the board of directors of the Minnesota Pollution Control Agency.

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for polluting 54 large rivers for 100 years above the safe drinking level, due to Sr-90 alone. The pilot facility is to hold 1000 waste canisters.

ERDA will be issuing an environmental impact statement by the summer of this year on their waste disposal plans; but they will not promise to include in it an analysis of the worst possible hazards or failures of a repository. In fact, a preliminary safety analysis won't be issued until 1980 and a final safety analysis won't be issued until possibly as late as 1985. Furthermore, the safety analysis report will probably not analyze the worst possible failure of a repository. The failures of concern here are twofold: (1) a sudden crack in the geology which breaches the naturally impermeable layer of rock that normally protects the salt formations from being dissolved by surface water, and (2) the existence of an undetected abandoned well hole through a repository area, either of which might allow surface water to expose and leach out the buried waste. ERDA's director of the civilian nuclear waste management program said that he does not know whether the technology exists to find all wells that may exist in a chosen disposal area. Also, geologists say that no reliable theory exists to use to rule out the formation of a catastrophic crack.

ERDA contends that surface storage concepts are still safe and they will be used if deep burial cannot be demonstrated to be safe. Thus, the forthcoming environmental impact statement should analyze the hazards of this option fully. However, there is no assurance from ERDA that the environmental statement will do so.

ERDA has no estimate of the cost of retrieving waste from a deep repository should the containment integrity be lost and the waste begins seeping into surface waters. ERDA would not rule out $30 billion or more in clean-up costs.

Among the various surface storage concepts, an air-cooled concept is now favored by ERDA which consists of a single shielded waste canister (10 feet in diameter and 20 feet high) which is stood out in the open on the ground. Ultimately, 25 million of such shielded canisters would be needed. This concept, too, has a meltdown accident possibility, if small internal air ducts should become plugged, according to my calculations. ERDA does not face the meltdown question squarely. A canister meltdown could cause agricultural and living restrictions over 150,000 square miles of land, due to Sr-90 and cesium-137 release, respectively.

Concerning the buildup of spent fuel in storage basins (pools) at nuclear power plants, ERDA is giving no consideration to the possibility of the spent fuel basins being ruptured and drained by a reactor explosion accident (or sabotage). In that event the spent fuel could overheat and melt, since the basin water is needed to remove the heat of the radiation. A storage basin could have three to five times more strontium-90 and cesium-137 radioactivity than would be present in the reactor core; so its rupture could greatly amplify the consequences of a reactor accident.

The following report elaborates on the above highlights and reveals other extremely serious hazards and uncertainties. The report also contains a number of recommendations for action to protect the public health and safety and for further studies. It is recommended that serious consideration be given to shutting down all reactors, in order to stop generating more nuclear waste, since safe waste disposal hasnot been established and because even the present rate of build up of waste is great in terms of contamination potential. The recommendation is further motivated by this author's evaluation of the accidents hazards of the nuclear power plants (see The Accident Hazards of Nuclear Power Plants, published by the Univ. of Massachusetts Press).

Plans should be prepared to separate plutonium from the existing waste and dispose of it by consuming it as fuel in small safe reactors, and then storing the rest of the waste in solid form in surface storage structures that are free of a meltdown possibility, until a safe deep burial facility can be established, which may take 100 years. The design of a safe small reactor would be elaborated on in a subsequent report of this author. Briefly, I have in mind a 60 MWe plant (6 percent of the size of today's big plants), modeled after the Navy's pressurized water reactors, to preclude further production of plutonium while plutonium inventories are consumed. Ten such plants would consume the present accumulation of plutonium from civilian reactors (21.3 tonnes; Willrich and Taylor, Nuclear Theft: Risks and Safeguards, p. 52) in 27 years--within the design life of such plants. (Five times the number of such plants could destroy by fissioning the existing weapon plutonium inventory, which is estimated at 100 tonnes.) Actually, the existing naval reactors could be candidate reactors for consuming the plutonium. They are already built, and are operated to strict standards. It is recommended further that the nation consider terminating the production of weapons plutonium and associated nuclear waste and the use of nuclear powered naval warships (rely on land-based missile systems to deter nuclear war), in order to stop generating more nuclear waste. Finally, the decision-making process for deciding the safety of waste disposal should be reviewed; and an independent panel of experts should be commissioned to evaluate the safety of nuclear waste disposal.

The first order of business is to seek full hazards analyses from ERDA and its laboratories; for they appear to be forming their argument of the safety of waste disposal on subjective estimates of failure probabilities without preparing to accompany their arguments with calculations of the consequences of the worst possible waste disposal system failures.

POSTSCRIPT

A considerable amount of nuclear waste has been created in producing plutonium weapon material at the Hanford Works in Richland, Washington and at the Savannah River Laboratory in Aiken, South Carolina. ERDA's environmental report for managing the waste at Hanford does not state the total amount of Sr-90 and Cs-137 in the nuclear waste; but I estimate that 60 to 250 million curies of Sr-90 and a like amount of Cs-137 are presently in storage at the Hanford site, based on data given in the report and elsewhere. Most of this radioactivity is stored in canisters placed in water-filled basins for heat removal. However, ERDA's environmental report does not analyze the accident hazards of these basins. Conceivably, a single basin could release 60 million curies of Sr-90 and Cs-137 into the atmosphere; which could virtually preclude agriculture in half of the U.S., and deny the inhabitation of over 500,000 square miles due to Cs-137 gamma radiation alone, by EPA's standards of maximum allowable radiation dose.

The remaining Sr-90 and Cs-137 at Hanford is stored in diluted liquid form (90 million gallons) in underground tanks. About 500,000 gallons of this waste has leaked into the ground, including about 100,000 curies of strontium-90. However, the leaked strontium and cesium appear to be well absorbed and trapped in the underlying soil and no contamination of the gound water is expected, according to ERDA's scientists. This leak represents about 3 percent of the strontium-90 and cesium-137 that is present in a large 1,000 MWe nuclear power reactor, or 1/2,000 of that which would be placed in ERDA's planned pilot repository.

CORRECTION*

The strontium-90 and cesium-137 said in the above postscript to be in storage in canister form at Hanford is not quite correct. According to an ERDA official, 10 to 20 million curies of each isotope is in such storage and 150 million curies of each are in the "process stream," that is, in the processing piping, due to be stored in the basins in canister form. Plans are being made to eventually make use of the radioactive materials for military and domestic purposes; for example, up to one million curies of cesium-137 would be used in a sewage treatment plant, which raises additional hazards questions.

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* Added subsequent to formal submission of statement to EPA.

APPENDIX A*

HIGH-LEVEL AND LONG-LIVED RADIOACTIVE WASTES: CONCEPTS AND COMPARISONS

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* Materials presented in this Appendix were produced through consultation with Dr. Keith Schiager, University of Pittsburgh, for the U.S. Environmental Protection Agency.

This Appendix is a survey of the origins, content, and potential hazards of the present inventory of radioactive waste in the United States. No attempt has been made here to project waste production in the future. The primary objective is to provide background material on certain aspects of the current situation for those readers who are not already thoroughly familiar with the subject. The major efforts here are a description of waste characteristics, and a comparison of the potential hazards (by aqueous pathways) of the constituent radionuclides.

I. SOURCES

Three major categories of radioactivity contained in wastes that exist in the United States at the present time are discussed:

1. Fission products generated by chemical processing of nuclear reactor fuel to extract most of the plutonium for the national defense program. (These are generally referred to as high-level defense wastes.)

2. Transuranic nuclides (man-made nuclides heavier than uranium-238) that remain in the high-level wastes, including the unextracted fraction of the plutonium.

3. Natural radioactivity contained in wastes from mining and milling of uranium and phosphate ores.

These three categories were selected because they represent both the high-level and the long-lived radioactive wastes that are of primary concern to many individuals. The sources and forms of these wastes will be described and compared in order to emphasize elementary concepts that must be considered in radioactive waste management and disposal.

The comparisons will be simplified by considering, within each category, only the most critical nuclides, i.e., those that contribute to or control essentially all of the potential radiation dose to humans. In the fission product category, only strontium-90 and cesium-137 are included; other products are of much lesser significance, either because of their much shorter half-lives, or because of their smaller activities and/or relative biological hazards.

The transuranics considered in these discussions are the plutonium nuclides 238, 239, and 241, and americium-241. Of the naturally occurring radionuclides, only thorium-230 and radium-226 are included. This is simply because the only basis for comparison of risks that will be used here is the dissolution of waste nuclides in water. The comparisons will not include external irradiation or inhalation of airborne radionuclides that would result from the radionuclides following radium in the uranium decay series. These hazards

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occur if wastes are left on or near the earth's surface, as is the current practice for mining residues. The procedure followed here therefore understates the hazards associated with mining wastes.

High-level radioactive wastes are presently stored at the three major Energy Research and Development Administration (ERDA) laboratories: Hanford Reservation in Richland, Washington; Savannah River Plant in Aiken, South Carolina; and Idaho National Engineering Laboratory in Idaho Falls, Idaho.* The high-level waste is stored in tanks as nearly solid salt cake and sludge, or calcined solids, and as liquid awaiting calcination or in the process of self-concentration by evaporation due to decay heat (Refs. 1-3). The wastes from uranium and phosphate mining are located near the mining and milling sites. Phosphate sites are located primarily in Florida; uranium sites, in the western states (Refs. 4-6).

The volumes and activities of the wastes currently in storage are summarized in the following sections. Materials not presently classified as wastes are not included even though they may fall into the same categories. For example, fission products and transuranics contained in unreprocessed reactor fuel elements are not included, nor are the large quantities of depleted uranium currently stored at enrichment facilities. Inclusion of these additional sources would change specific numerical values, but would not significantly change the general concepts addressed in the following sections. In particular, the relative hazard comparison presented in the final section would remain essentially the same.

II. VOLUMES

The current total volumes of radioactive waste from the three sources under consideration are depicted in Figure 1 (Refs. 1-6). For purposes of comparison, all volumes are expressed in gallons even though the wastes are not all in liquid form. The processes that generate the wastes are summarized for each of the major sources in the following sections.

PHOSPHATE INDUSTRY

Wastes from the phosphate industry are generated during several different steps of the production process, as shown in Figure 2.

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* Waste from commercial reprocessing of reactor fuel consists of 0.6 million gallons contained in one tank at Nuclear Fuel Services, Inc., West Valley, New York. This is less than 1 percent of the total defense wastes and is not included in this evaluation.

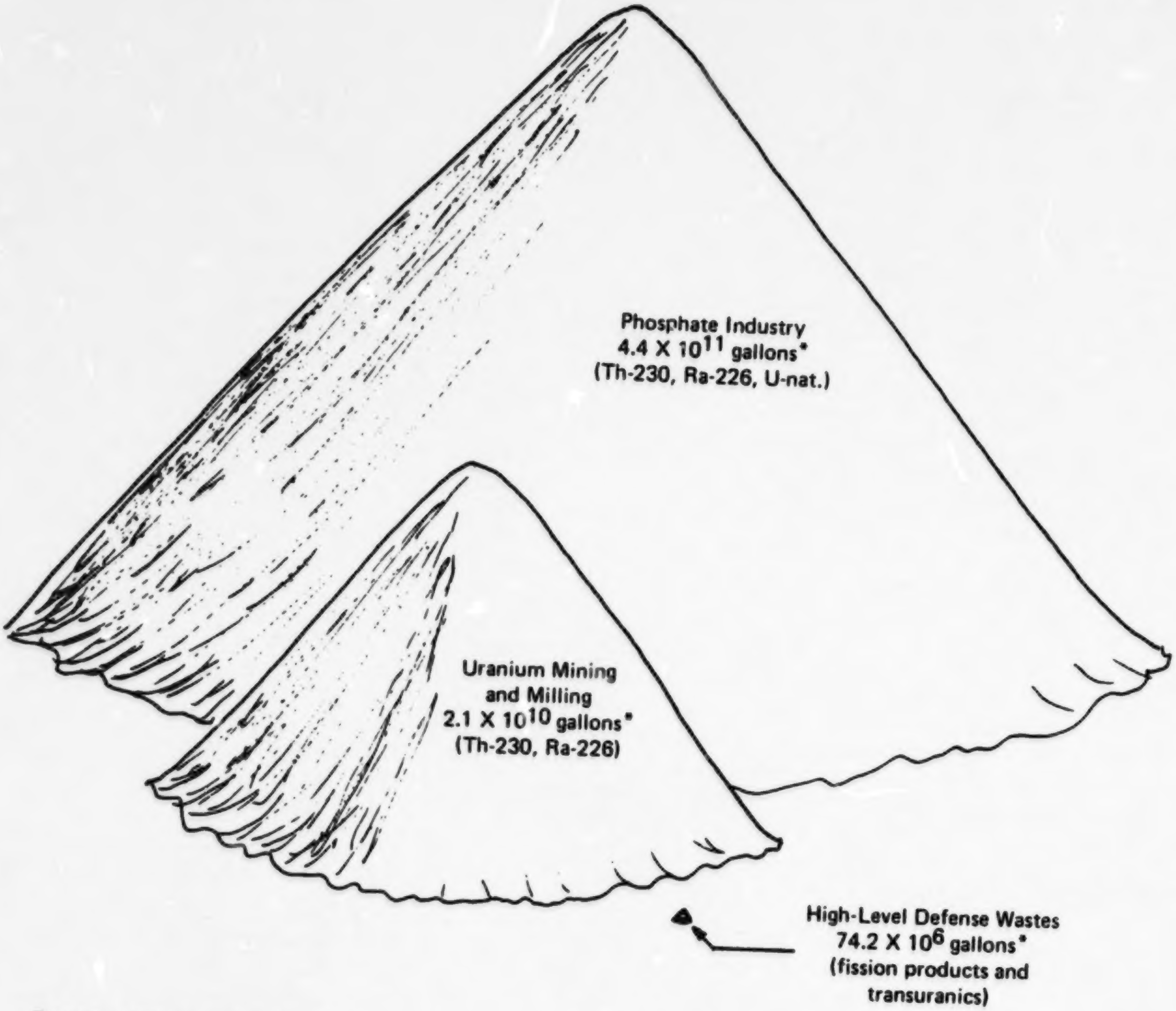

Figure 1. Volumes of radioactive wastes. *All numerical values contained in this summary represent the best approximation that could be derived from the referenced materials. The uncertainty associated with some of the values, however, may be as large as ± 25%.

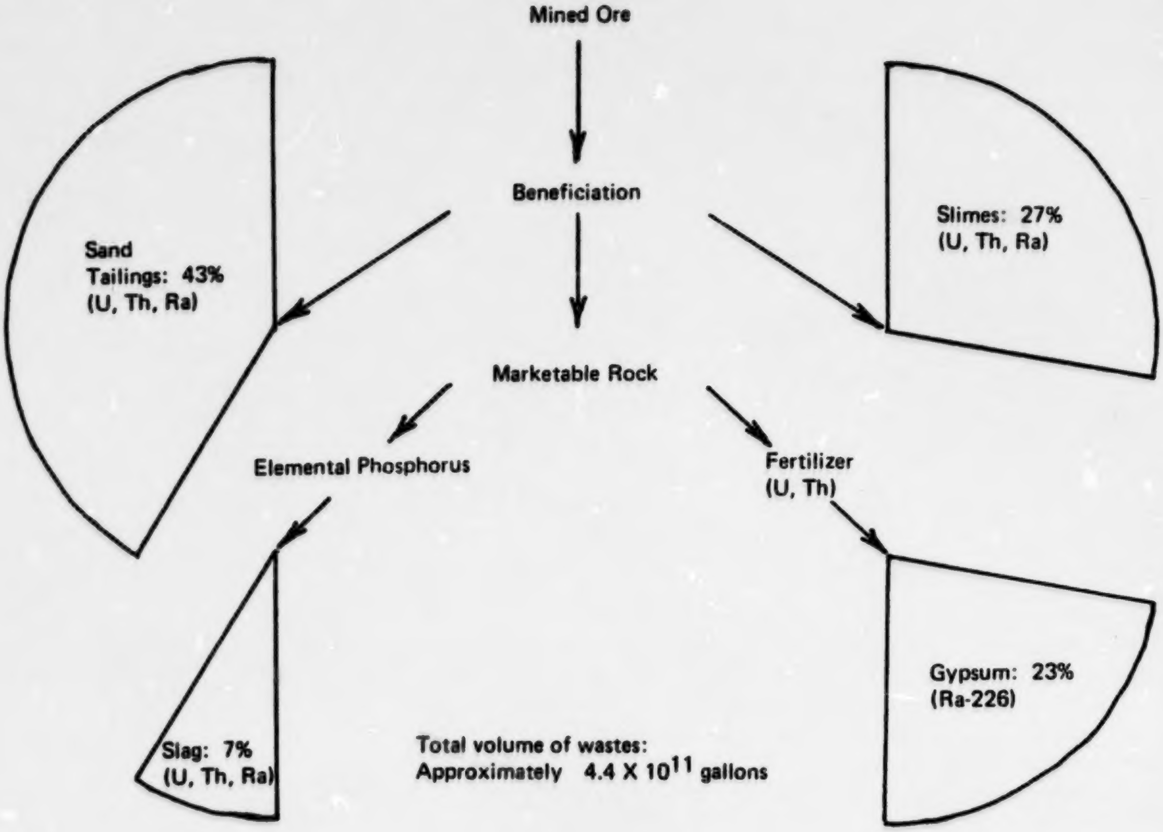
Mined Ore
Beneficiation
Sand
Tailings: 43%
(U, Th, Ra)
Slimes: 27%
(U, Th, Ra)
Marketable Rock
Elemental Phosphorus
Fertilizer
(U, Th)
Slag: 7%
(U, Th, Ra)
Gypsum: 23%
(Ra-226)
Total volume of wastes:
Approximately 4.4 X 10^11 gallons

Figure 2. Sources and relative volumes of phosphate industry wastes.

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The greatest quantities of wastes are generated during beneficiation and are in the form of sand tailings and slimes. Lesser amounts of gypsum from the production of fertilizers and electric furnace wastes (mostly slag) from the production of elemental phosphorus are also produced. The total volume of all wastes from the phosphate industry is nearly as large as the initial volume of the phosphate ore mined and is estimated to be approximately 4.4 X 10^{11} gallons. This volume would cover Washington, D.C., to a depth of 35 ft.

The significant radionuclides in these wastes (U-natural, Th-230, and Ra-226) are distributed among the sand tailings, slimes, and slag in approximately the same proportions and concentrations as found in the original ore. (If secular equilibrium exists in the ore, then the activities of U-238, Th-230, and Ra-226 would be approximately equal in three of the four waste fractions.)

In the wet chemical processes used for making phosphate fertilizers, some fractionation of the radioactivity occurs, with the result that uranium and thorium tend to stay in the fertilizer and radium is preferentially rejected to the gypsum waste. Reduced concentrations of uranium and thorium are also found in the gypsum, however, since the separation is not complete.

URANIUM MINING AND MILLING

The radioactive wastes from the uranium mining industry are predominantly in the form of mill tailings. After extraction of the uranium, the principal radionuclides in the tailings are Th-230 and Ra-226, which are nearly in equilibrium. The tailings consist of two fractions: slimes containing a large portion of the radioactivity, and sand tailings comprising most of the volume. However, these fractions are not necessarily separated during the milling process and may simply be mixed together for disposal. The volume of the tailings is about the same as the total volume of ore mined, because the uranium content of the ore is a very small percentage. The total current volume of tailings, at both active and inactive mill sites, is assumed to be equal to the total volume of ore mined to date, or approximately 2.1 X 10^{10} gallons (Ref. 4). This is approximately the volume of the Empire State Building.

LOW-LEVEL SOLID WASTE

Low-level solid radioactive waste consists of industrial and laboratory trash that is either contaminated, or suspected of being contaminated, with low levels of radioactive materials. The activity levels in this waste are generally too low to be easily measured, i.e., usually less than 10^{-6} Ci/ft^3 and less than 10 nanocuries of transuranics per gram (Ref. 15).

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After collection, low-level solid wastes are usually compacted to some degree in order to reduce the volume; they are then packaged in boxes or metal drums for transport to the disposal site. Burial facilities consist of concrete-lined or unlined trenches in which the waste containers are stacked and then covered with earth.

The total volume of low-level waste produced by ERDA laboratories in 1974 was about 61,500 m^3, and the estimated commercial waste produced in that year was about 54,000 m^3; these volumes are nearly equal, and together are equivalent to the volume of trash produced by a typical city of 100,000 inhabitants (Ref. 15). The total volume buried at both ERDA and commercial sites exceeds 1.5 million cubic meters, as shown in Table 1. Projections show that the commercially produced waste is to increase rapidly in the future (Ref. 16).

HIGH-LEVEL DEFENSE WASTES

The high-level defense wastes are produced and stored at the three ERDA production facilities previously identified (Hanford, Savannah River, and Idaho Falls). The high-level wastes containing fission products and transuranic nuclides may be in liquid or in one of three solid or nearly solid forms. Figure 3 illustrates the form and distribution of the high-level wastes among the three locations (Refs. 1-3, 7). The total volume of the high-level defense wastes is approximately 74.2 X 10^6 gallons, which is roughly equivalent to the capacity of an oil supertanker.

All of the high-level wastes are initially generated as liquids. At Hanford and Savannah River the nearly solid wastes are in the form of sludge and salt cake. The sludge is precipitated out of the liquid, and the salt cake results from partial evaporation of the liquid. This process results in about a 3.5-to-1 volume reduction.

Both the sludge and the salt cake are relatively soluble. The major nuclide in the sludge is Sr-90, while in the salt cake the major nuclide is Cs-137. Some of the liquid waste at Hanford has been reprocessed to remove Sr-90 and Cs-137. The extracted nuclides are metallized and doubly encapsulated and are not, thereafter, included in the "waste" inventory. To date, approximately 22 percent of the Sr-90 and Cs-137 activities have been removed from liquid waste inventories by this method.

At Idaho Falls, the solid wastes are calcined from the liquid. Calcination results in about an 8-to-1 volume reduction. These calcined solids are less soluble than the sludges and salt cakes (Ref. 13). There is no separation of radioisotopes in the calcination. Because of the various solidification processes employed, the remaining liquid wastes contain varying amounts of Cs-137 and Sr-90.

TABLE 1 LOW-LEVEL SOLID RADIOACTIVE WASTES BURIED AT ERDA AND COMMERICAL SITES(f)

	Volume(a) (m^3)	Activity(b) (MCi)	Total Transuranics (kg)	Estimated Retrievable TRU (kg)
ERDA Sites:(c)	1.194×10^6	16.56	937	215
Commercial Sites:(d)	0.37×10^6	3.30	1,000	--(e)
Total	1.564×10^6	19.86	1,937	215

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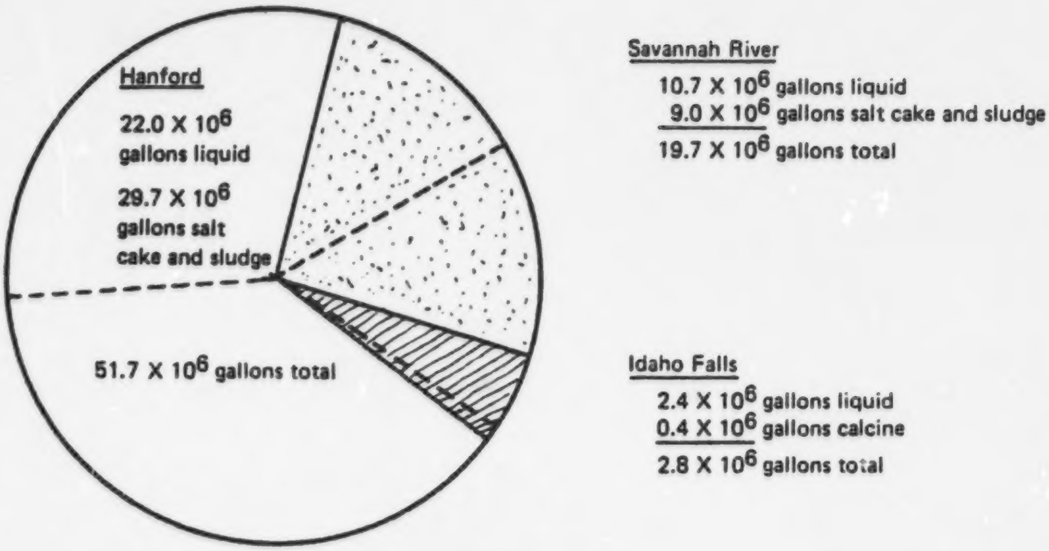
a. Partially compacted.
b. Not corrected for decay since burial.
c. The major ERDA sites for storage and burial of low-level wastes are Richland, WA; Idaho Falls, ID; Los Alamos, NM; Oak Ridge, TN; and Aiken, SC.
d. Most of the commercially or privately produced waste has been disposed of in one of the six commercially operated burial sites: Beatty, NV; Maxey Flats, KY; Sheffield, IL; Barnwell, SC; West Valley, NY; and Richland, WA.
e. Very little.
f. Source: Refs. 14-16.



High-level waste total volume: 74.2 X 10^6 gallons

Figure 3. Distribution of high-level defense waste of volumes.

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III. ACTIVITY

The activities of the radionuclides of interest are listed in Table 2. The activities were derived from the summation of the waste inventories at the three ERDA facilities and for the entire uranium and phosphate mining industries (Refs. 1-7). All activities listed have been corrected for decay through 1976. The activities of Sr-90 and Cs-137 shown in Table 2 were derived from an inferred Cs:Sr activity radio of 3:2 (Refs. 1-3). The activity estimates for the individual transuranic nuclides were made by applying the isotopic ratios of the spent fuels at Hanford and Savannah River to the proportionate fractions of the total mass of 625 kg of plutonium waste. Although the total mass of plutonium waste is known to within ±25 percent (Ref. 1), the uncertainties in the estimates of individual activities of the transuranic nuclides are somewhat greater.

In order to illustrate the changing nature of radioactive wastes, the activities remaining after 500 years are also included in Table 2. In that period of time, the activities of Sr-90 and Cs-137 will decrease by more than 100,000 times. Plutonium-238, the major constitutent of transuranic waste today, will decrease in 500 years to less than 2 percent of its present activity. Plutonium-241 will disappear in 500 years, but since it decays to Am-241, it will add a small amount to the americium inventory (Figure 4). Because of its 24,000 year half-life, the inventory of Pu-239 will not be significantly reduced in only 500 years.

The waste activities of the uranium and phosphate mining and milling industries are comparable, both at present and after any decay period. The relative activities of all the wastes are illustrated in Figure 5.

IV. RELATIVE HAZARD INDEX

In order to compare the radiation hazards that may be represented by the various categories of radioactive wastes, a single index of hazard is desirable (Ref. 10). The index selected for this analysis is the volume of water that would be needed to dilute all of the radioactivity in the wastes to the concentration limit for continuous exposure of the general public, as specified in 10 CFR 20 (Ref. 11). Thus, a relative hazard index (RHI) is defined as the total activity of a particular constituent of the radioactive waste inventory divided by the radioactivity concentration guide (RCG) for that constitutent in water. The values of the RHI (in gallons) for current inventories of radioactive wastes, and for the same wastes at a time 500 years in the future, are shown in Table 3 and Figure 6.

The short-lived high-level wastes, primarily Sr-90 and Cs-137, require the most dilution today; Sr-90 is the primary hazard.

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TABLE 2 RADIOACTIVITY CONTENT OF EXISTING WASTES(a)

	Nuclides	Isotopic Activity (Ci)			
		Present		500 Years in Future	
Fission products	Sr-90	1.8×10^{8}	4.4×10^{8}	1.1×10^{3}	3.8×10^{3}
	Cs-137	2.6×10^{8}		2.7×10^{3}	
Trans-uranics	Pu-238	1.0×10^{6}	1.3×10^{6}	1.8×10^{4}	1.5×10^{5}
	Pu-239	3.3×10^{4}		3.3×10^{4}	
	Pu-241	1.8×10^{5}		--	
	Am-241	1.0×10^{5}		1.1×10^{5}	
Phos-phate mining	Ra-226	7.9×10^{4}	2.2×10^{5}		2.2×10^{5}
	U-nat	6.8×10^{4}			
	Th-230	6.9×10^{4}			
Uranium mining	Ra-226	7.1×10^{4}	1.4×10^{5}		1.4×10^{5}
	Th-230	7.1×10^{4}			
	Total Activity		4.4×10^{8}		5.2×10^{5}

(a) Source: Refs. 1-7.

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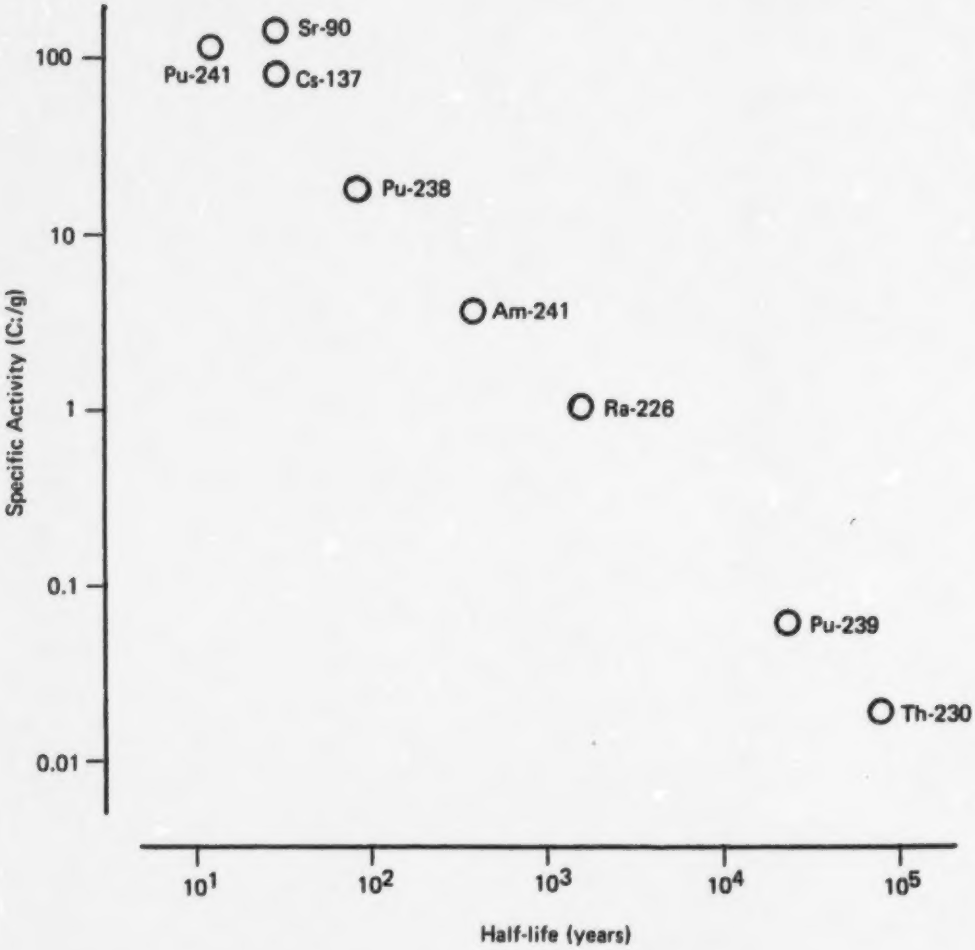

Figure 4. Specific activity versus half-life.

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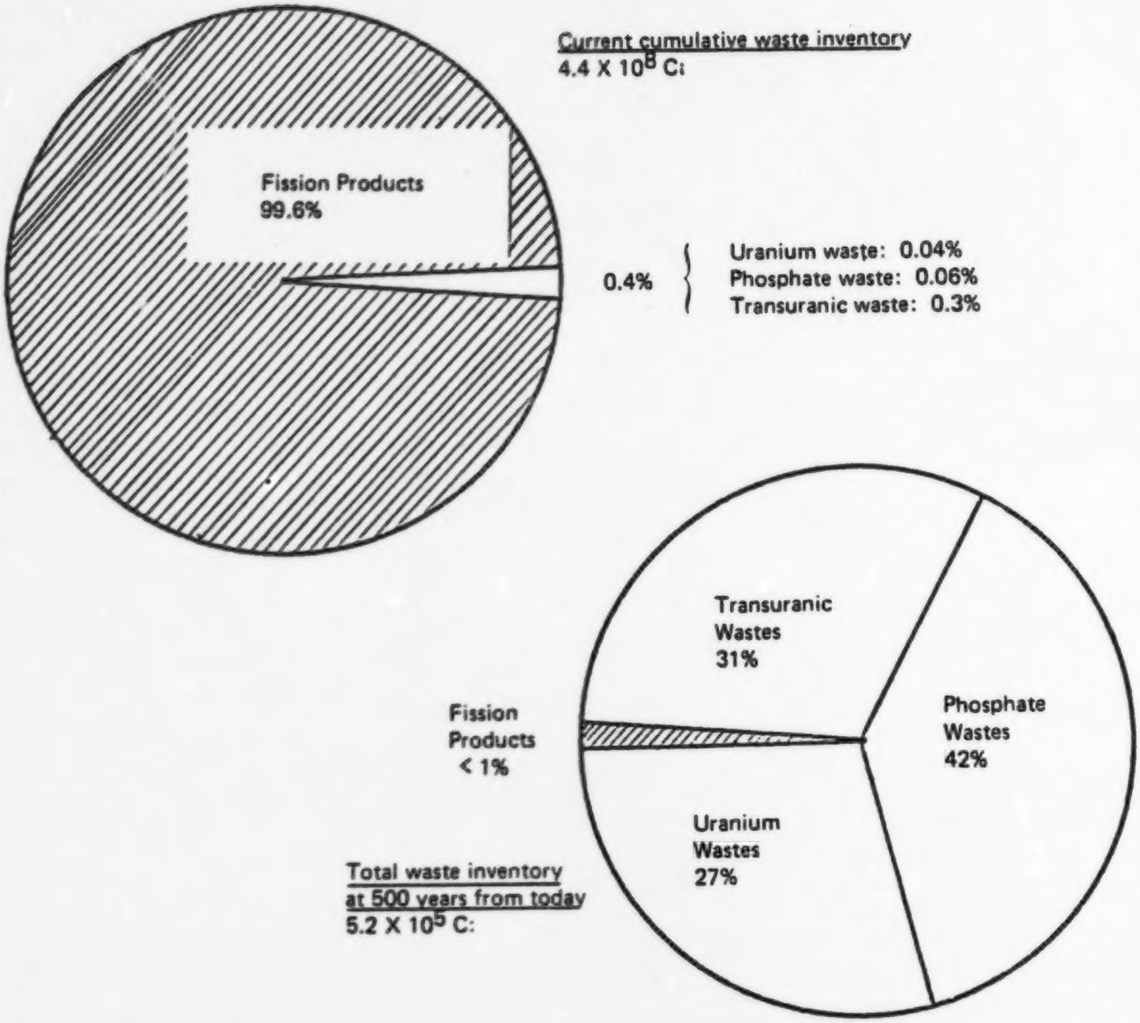

Figure 5. Percentage activities of current waste inventories at present and after 500 years.

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TABLE 3 RELATIVE HAZARD INDEX (RHI) FOR CURRENT INVENTORIES OF RADIOACTIVE WASTES

Origin	Nuclides	RCG[a] (Ci/gal)	Relative Hazard Index (gallons) Current	Relative Hazard Index (gallons) 500 Years Future
High-level Fission Products	Sr-90	1.1×10^{-9}	1.6×10^{17}	1.0×10^{12}
	Cs-137	7.6×10^{-8}	3.4×10^{15}	3.6×10^{10}
			1.6×10^{17}	1.0×10^{12}
Trans-uranics	Pu-238	1.9×10^{-8}	5.3×10^{13}	9.5×10^{11}
	Pu-239	1.9×10^{-8}	1.7×10^{12}	1.7×10^{12}
	Pu-241	7.6×10^{-7}	2.4×10^{11}	-
	Am-241	1.5×10^{-8}	6.7×10^{12}	7.3×10^{12}
			6.2×10^{13}	1.0×10^{13}
Phosphate mining and milling	Ra-226	1.1×10^{-10}	7.0×10^{14}	7.0×10^{14}
	U-nat	1.1×10^{-7}	5.9×10^{11}	5.9×10^{11}
	Th-230	7.6×10^{-9}	9.1×10^{12}	9.1×10^{12}
			7.1×10^{14}	7.1×10^{14}
Uranium mining and milling	Ra-226	1.1×10^{-10}	6.3×10^{14}	6.3×10^{14}
	Th-230	7.6×10^{-9}	9.4×10^{12}	9.4×10^{14}
			6.4×10^{14}	6.4×10^{14}

(a) Radioactivity concentration guide.

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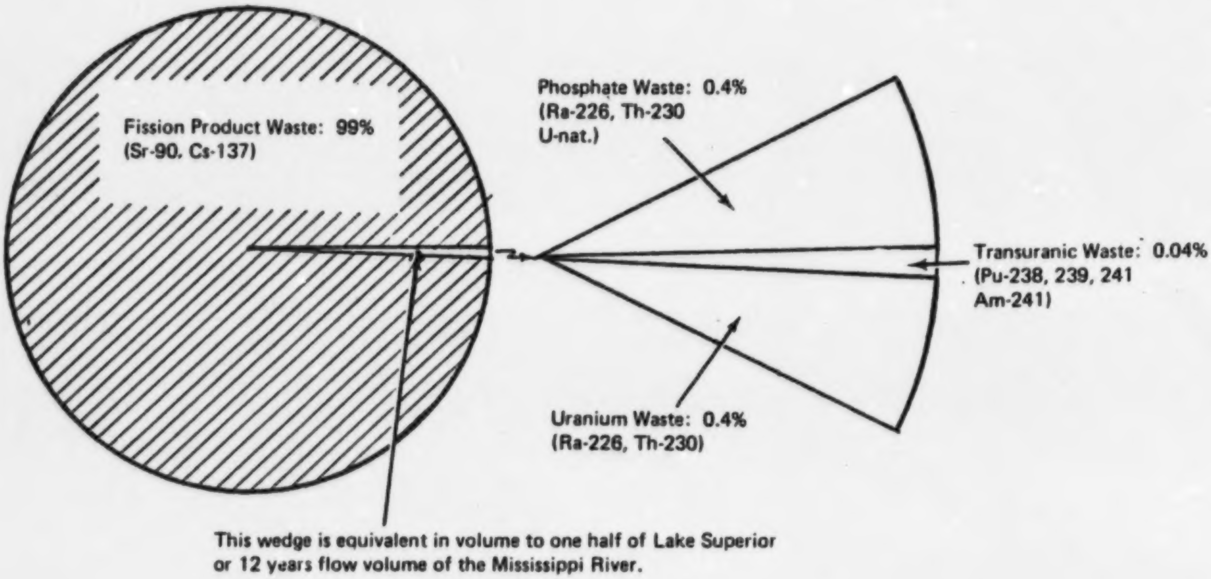
CURRENT WASTE INVENTORY



CURRENT WASTES AFTER 500 YEARS

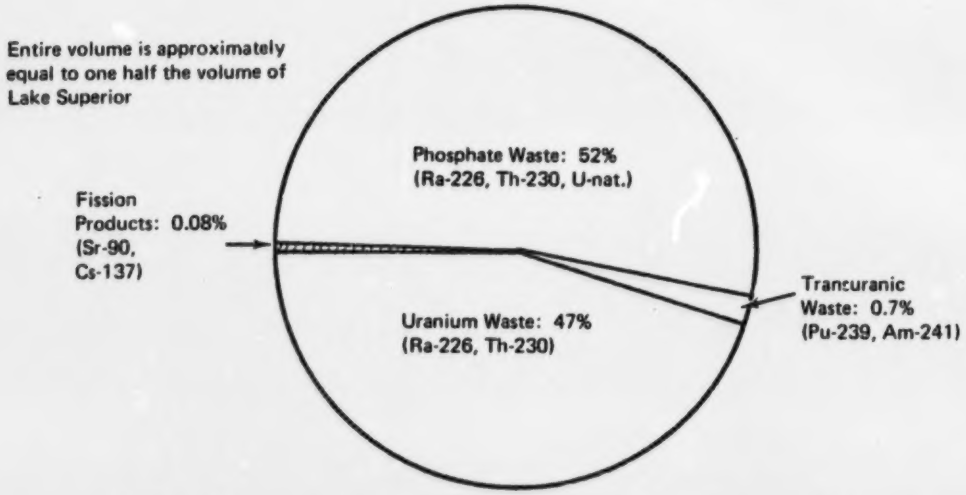


Figure 6. Percentage relative hazard index (RHI) based on water volume required to dilute to RCG.

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They require much more dilution than the long-lived high-level wastes Pu-239 and Am-241. For comparison, the water needed to dilute present mine wastes is about one half the volume of Lake Superior. In 500 years the situation changes dramatically. Cs-137 and Sr-90 have decayed to a very small fraction of the total hazard, and the hazard from the other nuclides remains essentially unchanged. Uranium and phosphate wastes are a greater relative hazard than either fission products or transuranic wastes.

V. GENERAL CONCEPTS

1. In recently separated reactor wastes, the radiation hazard from fission products will be orders of magnitude greater than that from transuranic nuclides.

2. Within a few centuries after the production of reactor wastes, the fission products will have decayed to the point that their contribution to the total radiation hazard is a very small fraction of the total.

3. In terms of total radioactivity potentially available to the biosphere and the corresponding relative hazard index, the wastes from mining and milling of radioactive ores are of far greater significance than the transuranic nuclides produced in nuclear reactors.*

4. If the linear, nonthreshold model of radiation effects is assumed to be correct, the cumulative radiation dose potentially available to the total population (represented by the RHI) is a valid measure of the relative toxicity and risk associated with each category of radioactive waste. The particular distribution of the waste materials and specific modes of entry into the biosphere would be of lesser importance.

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* Recall, however, that much of the transuranic content of spent fuel from defense programs has been extracted during reprocessing operations. This separation may or may not be performed on spent fuel from commercial power reactors.

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APPENDIX GLOSSARY

Activity - A measure of the rate at which nuclear disintegrations occur, usually expressed in curies (Ci).

Beneficiation - A process that increases the concentration of a desired mineral in an ore.

Calcination - Solidification method for disposal of liquid wastes involving atomizing and coating of liquid on small granular solids and heating to drive off moisture.

Concentration - The activity per unit volume of any material.

Curie (Ci) - The basic unit of radioactivity of a material. One curie is approximately 37 billion disintegrations per second or approximately the radioactivity of 1 g of radium.

Decay - The spontaneous radioactive transformation of one nuclide into another.

Half-life - The time in which half the atoms in a radioactive substance disintegrate.

High-level Wastes (as used by ERDA) - Wastes from the operation of the first cycle extraction system consisting of essentially all of the nonvolatile fission products, small amounts of uranium and plutonium, and other heavy elements.

Nuclide - Any atomic nucleus specified by its atomic weight, atomic number, and energy state.

Radioactivity - The spontaneous decay or disintegration of unstable atomic nuclei accompanied by the emission of radiation.

Radioactivity Concentration Guide (RCG) - The maximum concentration of radioactive materials in air or water to which an individual may be continuously exposed without exceeding an established dose limit.

Specific Activity - The activity per gram of a nuclide, an element, or a chemical compound.

Tailings - The portion of ore remaining after a mineral has been extracted.

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APPENDIX B

ATTENDEES AT THE ALBUQUERQUE WORKSHOP

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